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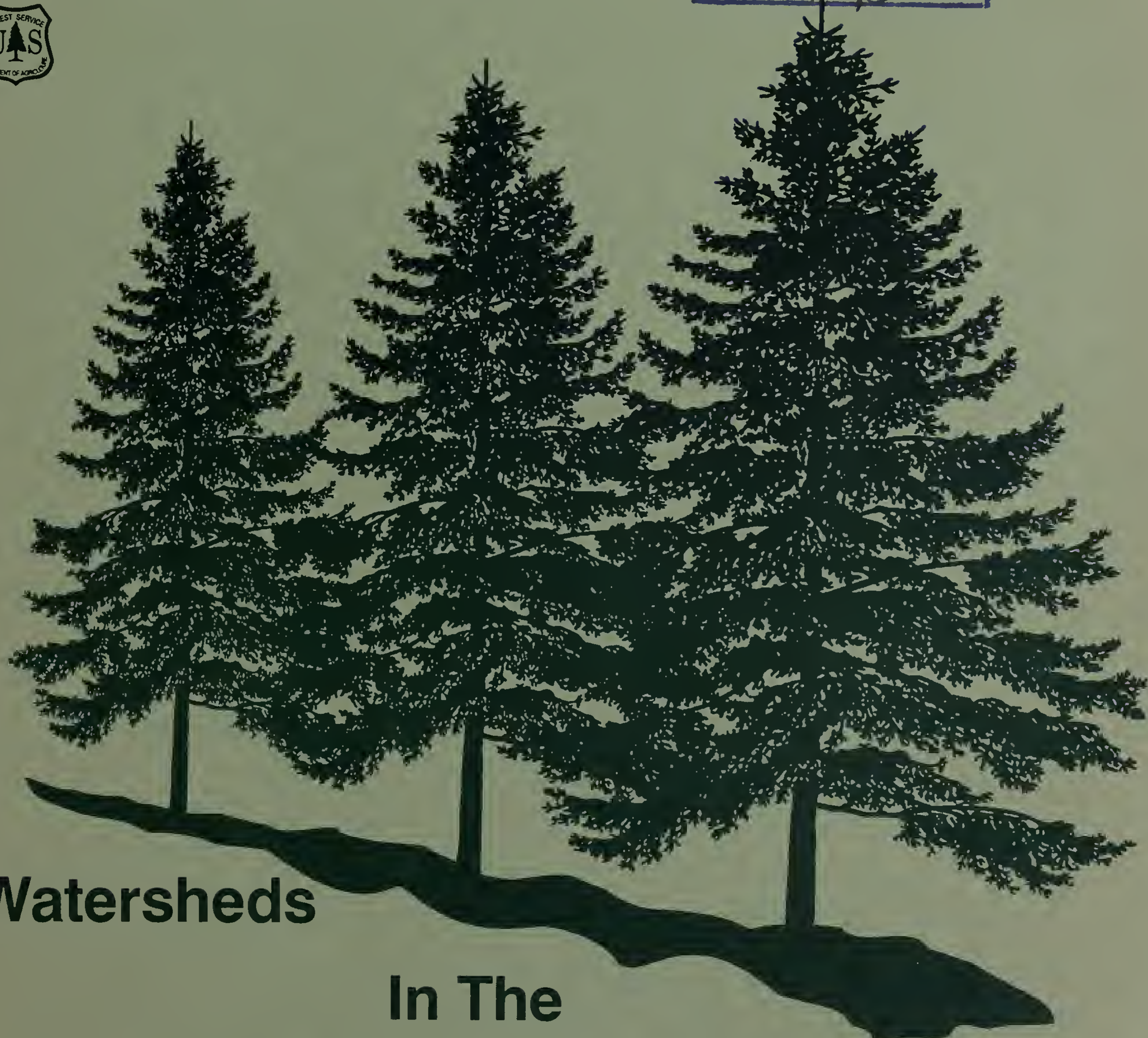

Watersheds In The Nineties

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Abstract

This publication contains 30 papers from the USDA Forest Service National Hydrology Conference held in Phoenix in May 1992. Topics include Cumulative Effects, Forest Service External Responsibilities, Aquatic Ecology, Monitoring, Large Woody Debris, Nonpoint Source Management, Riparian Areas, Water Rights, Fluvial Geomorphology, Land Management Planning, Coastal Zone Management Act, Channel Maintenance, Sediment Modeling, Wetlands, Watershed Rehabilitation, Data Management, and Marketing Hydrology Programs.

Keywords: hydrology, watershed, drainages, aquatic, streams, riparian.

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National Hydrology Workshop: Watersheds In The Nineties

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Abstract.--The Keynote Address contained in this paper presents objectives of the Third National Hydrology Workshop. It identifies the roots of watershed management in the Forest Service, current issues, examples of successes, challenges for the future, and expectations for the 1990s.

INTRODUCTION

It's a pleasure to be in Phoenix to help you kickoff the Forest Service's (FS) National Hydrology Workshop—"Watersheds in The Nineties"—Win with Stewardship. This is also National Soil and Water Stewardship Week so, from this perspective, the Workshop is timely. I feel very good about this week and the excellent opportunity we have to grow professionally and to network with each other.

This is our third National Hydrology Workshop, but the first since 1978. As a society and as an agency, we have experienced many changes in the last 14 years. The focus of this workshop is to help you be a more effective hydrologist in these changing times. This is a "workshop" and not a conference, so that together we can work on three objectives:

1. Strengthen and improve technology transfer among hydrologists in National Forest Systems (NFS), Research, and State and Private Forestry, to allow practicing professionals to benefit from each other's past experiences and strengths.
2. Increase technical skills of hydrologists to deal with issues related to the wildland hydrology profession.
3. Share ideas and develop strategies for moving water resources management into the 1990s and beyond.

Keeping these objectives in mind, I now want to focus on: roots, issues, successes, challenges, and expectations.

OUR ROOTS

Since many of you are new to the agency, I think it would be helpful to look back now at our "roots" before we look ahead to the 1990s and beyond. As an agency, the FS has a long history of leadership in Water Resources Research and Management. The first forest reserves were created in 1891. The agency's involvement in research dates back to the early 1900s starting with the Wagon Wheel Gap paired-watershed experiment in Colorado. Our involvement with states and private forest landowners began when Gifford Pinchot was Chief. Concern for watershed management by the American people is also not new.

The entire conservation movement in America started with deep concerns over forested watersheds that were first expressed in the 1864 book "Man And Nature" by George Perkins Marsh. Marsh's influence from 1864 to 1900 on Congress, natural scientists, and presidents was pervasive and led to the protective legislation in the 1890s which started America on a different course of managing its forests than earlier societies which had exploited them to death. Marsh's writings and speeches were stirring and convinced many Americans that their economic survival depended upon respect for nature; not upon conquering her!

In 1891, Congress created the first forest reserves out of the public domain of the Louisiana Purchase in an attempt to halt the destructive logging and grazing

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practices of the time and to protect the ability of forested watersheds to release a steady flow of water to downstream communities. The goals were to preserve forested watersheds as a source of sustainable timber and water supplies, while trying to avoid the adverse consequences of erosion: deposition of unwanted sediment and debris in channels; shifting of channels; the destruction of buildings, bridges, roads, and other structures.

Later, in 1897, the Organic Act was passed. This Act clearly states the two purposes of National Forests (NF) as: "No National Forest shall be established, except to improve and protect the forest within the boundaries, or for the purpose of securing favorable conditions of water flows, and to furnish a continuous supply of timber ..."

In 1911, Congress passed the Weeks Act. This Act identified the primary reason for acquisition of NF lands: "The Secretary of Agriculture is hereby authorized and directed to examine, locate, and purchase such forested, cutover, or denuded lands within the watersheds of navigable streams, as in his judgment may be necessary to regulate the flow of navigable streams or for the production of timber."

As the first Chief of the FS, Gifford Pinchot was influenced by Marsh and he wrote the following in his own book, "The Fight for Conservation," in 1910: "The connection between forests and rivers is like between father and son. No forests, no rivers." And ..."Every river is a unit from its source to its mouth. Its uses are many and with our present knowledge, there can be no excuse for sacrificing one use to another if both can be served."

As you can see, even at the turn of this century, the FS Chief well understood and practiced watershed management! Our watershed work in the early years focused on land reclamation, and much of the work on the National Grasslands was in response to the Bankhead-Jones Farm Tenant Act of 1937. This Act directed the Secretary of Agriculture to develop a program to correct past land abuses of acquired farm lands. Many eastern and southern NFs as well as grasslands' areas were formed through the acquisition of "The lands that nobody wanted" (to quote the title of a book on the NFs east of the Rocky Mountains by The Conservation Foundation).

These lands had been extensively cut-over, farmed, and mined to the extent that soil erosion was rampant and sustaining vegetation was absent. Our NFs and grasslands today show the benefits of these early efforts to heal the land.

More recently, legislation such as the National Forest Management Act, the National Environmental Policy Act (NEPA), and The Clean Water Act (CWA) tell us that "water" is still a major environmental issue. The latest resources planning act assessment identified water resource issues as "high priority for research," and all four of the high-priority themes that provide the framework for the 1990 program address water, either directly or indirectly. The four themes are:

- Enhancing recreation, wildlife, and fisheries resources.
- Ensuring that commodity production is done in an environmentally acceptable manner.
- Improving scientific knowledge about natural resources.
- Responding to global resource issues.

I'd like to close this look at our "roots" by sharing some of Aldo Leopold's thoughts on the health of the land as he stated them more than 40 years ago in "A Sand County Almanac" (1949). I find Leopold's words appropriate for several reasons, one of which is that this "vision" is being carried forward today with the work of his son Luna — who will be joining us at this Workshop. Let's look at what Aldo said about the health of the land:

"There are two organisms whose processes of self-renewal have been subjected to human interference and control. One of these is man himself (medicine and public health). The other is land (agriculture and conservation) ....The effort to control the health of the land has not been very successful. It is now generally understood that when soil loses fertility, or is washed away faster than it forms, and when water systems exhibit abnormal floods and shortages, the land is sick .... In general, the trend of evidence indicates that in land, just as in the human body, the symptoms may lie in one organ and the cause in another. The practices we now call conservation are, to a large extent, local alleviations of biotic pain. They

are necessary, but they must not be confused with cures. The art of land doctoring is being practiced with vigor, but the science of land health is yet to be born."

I wonder what Aldo Leopold would say today about our focus on ecosystems?

ISSUES

America is faced with changing public values about natural resources and their uses. The public is becoming more and more concerned about maintaining a healthy environment, in part because environmental health directly affects human health. Growing scientific understanding of the interrelationships between ecosystem components and human health has helped fuel this concern.

Public concern has been translated into national legislation, such as the NEPA and the CWA. It is also expressed through state and local legislation and regulations to avoid environmental degradation. It is clear that changes are taking place in societal needs and values that intertwine with natural resources. The future direction of FS programs which respond to these societal needs must incorporate solutions to some of the public's environmental issues.

Our solutions will not be "for the environment" and "against human needs," but they need to achieve a balance between human needs and the environment. It is as if we are "managing in a fish bowl," and all eyes are on us; observing what and how we do something and expecting us as stewards of public lands to meet higher quality standards than private landowners.

Let us now look at some of the issues that you as a hydrologist and we as an agency face. Water is becoming one of the most important resources we manage. There is an increasing awareness of water resource issues by the American public and by Congress. Without a doubt, the water resource will become of greater and greater importance in the future, both in terms of quantity and quality.

For example, Congress has begun deliberation on reauthorization of the CWA. Congress has modified it 26 times since its passage in 1956. This Act is already a technically complex piece of legislation. The new Act will likely be even more complex. There is interest in tightening state controls on nonpoint sources of pollution. This will have a major impact on the way we do business.

Because Congress gives states primacy for water quality, federal agencies must comply with state requirements. State programs include land use requirements, as well as how we conduct land management practices.

Under existing CWA legislation, the Environmental Protection Agency (EPA) has published stormwater discharge regulations that may require permits for activities where no permits were previously required. Compliance will be technically complex. The EPA is continuing to bring existing nonpoint sources under the Point Source Permit Program.

Congress enacted a Coastal Zone Management Act last November. It identifies a state program for control of activities that cause nonpoint source pollution, and which impact the coastal zone and coastal resources. This could result in a redefinition of coastal zone boundaries to include the uplands. It will require the development of required management measures under a regulatory program. Congress continues to consider legislation for the protection of wetlands.

There will be increasing competition for water in water-short areas. We will continue to be involved in issues related to water rights litigation and quantifying instream flows needed to maintain channel integrity. Research is shifting its program mix in the 1990 Resources Program Assessment toward more dollars and emphasis devoted to recreation, wildlife, fish, and water research. Long-term data collection efforts on water quality are being maintained with some increase in environmental monitoring and developing scientifically sound management strategies that insure a reliable supply of clean water from forests and rangelands.

Major concerns remain for research to address. We need to better understand how human activities superimposed upon natural processes affect ecosystems and the water resources they include to minimize harm to the environment and ourselves. Are Best Management Practices (BMPs) doing the job they are designed to do? Are BMPs adequately defined? Are BMPs being applied? Research can evaluate the effectiveness of BMPs under experimental controls but effective monitoring techniques are needed to verify their effectiveness under a wide range of conditions. Both surface and ground water resources are involved.

To ensure this research is available and effectively used, we need to give increased attention to training our present specialists, to recruiting promising scientists, and to providing effective technology transfer. There are many more issues, but without listing them it is evident there is considerable interest in water resources. We can expect increased interest in our programs, both internally from the Department and externally from other federal agencies, states and the American people.

These issues, and the need to ensure our FS hydrologists are ready to address them, have been the focus of the agenda for this Workshop.

SUCCESSES DEMONSTRATE GOOD STEWARDSHIP

Many of you are doing outstanding watershed work that we are proud of. I encourage you to continue putting forth your best efforts to improve watershed conditions, to be effective members of interdisciplinary teams, to design and carry out effective monitoring programs, to educate the public and other FS employees about proper management of watersheds, wetlands, and riparian areas.

We are proud of the new bridges being built between research hydrologists and their clients, including state agencies and NFS hydrologists, private consultants, universities, interest groups, and others. We need the best hydrologic science you can practice and we need it communicated in ways that are most useful to all of us.

We also want to celebrate the vital and growing role that both State and Private and International Forestry branches are playing in helping thousands of Americans and people in other nations benefit from applying knowledge of how forested watersheds function to their lives.

To name a few examples: We are proud of the Chief's stewardship award winners and all the nominees .This award recognizes units and/or individuals for outstanding stewardship accomplishments leading to the protection and improvement of soil, water, and air resources. It is getting harder to select the winner for this prestigious $50 thousand award each year as the number of nominees and the quality of the applications has risen. Some 102 applications have been submitted since this award began in 1987.

Winners

1987- Oconee Ranger District of the Chattahoochee-Oconee National Forest, R-8

1988 - Francis Marion/Sumter NF, R-8 and Dr. Walter Megahan of Intermountain Forest and Research

1989 - Caribbean NF-Institute of Tropical Forestry and Dr. Douglas Fox of the Rocky Mountain Forest and Range Experiment Station

1990 - Lake Tahoe Basin Management Unit, R-5 1991 - Uinta NF, R-4.

We are pleased to hear about the "living watershed project" which was born from the Chief's stewardship award to the Lake Tahoe Basin Management Unit in 1990. It is a partnership with the Lake Tahoe Unified School District to develop a watershed curriculum for some 500 sixth grade students complete with Curriculum Outline, Teacher's Guide, and Activity Handbooks. The goal is to promote a good watershed ethic in local children who will be responsible for protecting Tahoe's delicate environment in the 21st Century.

We are proud of your innovative efforts to accomplish watershed improvements. Since 1981, our accomplishments total almost 120,000 acres; with 49 percent, or 58,000 acres, accomplished in the last 3 years. Much of this is the result of increased emphasis by Congress for improving watershed conditions. This work lends itself well to partnerships and volunteer groups. Continue to expand those avenues! It is a great way to get people caring for their watersheds!

We are happy to see the Riparian Improvement Strategy taking root on the NFs and grasslands, like the Quinn River Project on the Humboldt NF in Nevada, the Catfish Lake Project on the NFs of North Carolina, and in all the regions which are actively pursuing the six goals of this strategy.

We are happy to see the good work being done to quantify water right claims on many forests under trying circumstances and over many years —that is vitally important to the agency. We are encouraged by the water quality monitoring efforts you are making and by the growing cooperation between the NFS and research branches. We are proud of our new Stream Systems Technology Center, a joint-venture

between Research and NFS that will focus on getting knowledge and techniques related to fluvial systems into the hands of users more effectively over the next 5 years.

CHALLENGES

Major challenges for the FS in the future include meeting our responsibilities for Water Resource Management on the 191 million acres of NFS, providing assistance to the international community and to the states on matters related to forest management on State and Private Forestlands, and conducting necessary research. I believe that we can and will meet these challenges by working together.

Challenges to you as hydrologists are many and varied. Increase your technical knowledge, skills, abilities and your program management skills so you are viewed as a role model for other specialists. Advocate good land stewardship in all the tasks you do and show your line managers how to carefully manage the watershed resource. Educate your line managers on the requirements of the CWA, that states have primacy and that FS policy is to comply with state requirements for protection of water quality to the same extent as any nongovernment entity.

Promote the agency's nonpoint and riparian strategies, and take a leadership role in identifying actions to achieve the strategy goals on your unit. Focus on road locations and stream crossings since this activity continues to be the source of many of our water quality problems. Seek out and work with your state and EPA water quality people. Demonstrate that you are willing to work with them to address their water re source concerns.

"Wear the other shoe," and seek to understand why the public is concerned with our management; identify what you can do through various activities (monitoring, show me trips, etc.) to show them we are committed to high quality resource management of the national forests. Advocate ecosystem management and demonstrate that ecosystem management must consider the interrelationships between the terrestrial, riparian, and aquatic ecosystems. Seek out local members of organizations like trout unlimited and the American Rivers Council. Begin to develop partnerships similar to what the Washington Office is doing with these advocacy groups at the national level.

Improve communications and working relations with your soil scientist to strengthen the effectiveness of the watershed program. Improve communications and working relations with your internal partners (ecologists, fish biologists, silviculturist, etc.) to strengthen your interdisciplinary teams and the implementation of your Forest Plans. Seek out your local Research Unit. Ask their advice on technical issues and provide input into their Research Work Unit Descriptions that reflect future regional or forest needs.

Serve on their project steering committees if asked. Invite project scientists into your office to talk about their research results and how to properly use their information in land management planning. "Think beyond the green" and initiate expanding relations between NFS, Coop Forestry, and Research to better understand our individual roles and responsibilities to identify barriers to interagency cooperation and to promote cooperative efforts. In fact, I met with Al West, Deputy Chief for State and Private Forestry, 2 weeks ago and we agreed to work together to set up a $2 million dollar fund for NFS hydrologists to concentrate on closer working relation ships with state agencies on watershed issues like water quality, inter mingled watersheds, and so forth. Stay tuned as this effort develops.

Above all, be a missionary and not a zealot for good stewardship; demonstrate that healthy watersheds are the framework for assuring the success of our more visible programs such as "Rise to The Future," "Recreation —Great Outdoors," and "Wild And Scenic River Management."

EXPECTATIONS

The Workshop agenda was developed to address most of the issues the Workshop Planning Team believed were the key issues facing FS hydrologists. You are the customers to the team that planned this Workshop, so as you actively participate during this week you need to judge how effectively this Workshop addresses these issues and meets the expectations you have. Please share your comments with the team during the week.

In some sessions you'll be introduced to agency prescribed solutions; in other sessions you will be exposed to one technique that worked —whereas many others may also work. While some of the issues

have clear agency policy for their resolution, others do not and their resolution is open for discussion and debate this week and beyond.

We expect you to seek out and attend those sessions you feel will provide you the "nutrition" you need to grow as a hydrologist. Take personal initiative to reach out and increase your knowledge, skills, abilities, and also your program management skills. Do not shy away from the "softer" concurrent sessions like "Politics of Watershed Management," "Career Development," "Effective Presentations," and others. These sessions have much to offer.

A hydrologist who cannot or will not share his or her technical knowledge with nontechnical audiences is not an effective hydrologist. Being an effective hydrologist is more than being technically competent—it is also being able to market yourself and your program so that when you leave, the line officers or leadership team asks" When does the new hydrologist report?" rather than, "Why do we need a hydrologist?"

For the FS to succeed in the 1990s and beyond, we need your involvement to ensure that favorable conditions of water flow are maintained even as we manage the NFs for a variety of other goods and services.

To maintain favorable conditions of water flow, we must manage for healthy watersheds. We have improved the health of NF and grassland water sheds in the last 100 years; we need to continue these efforts. Healthy watersheds demonstrate good stewardship. Good stewardship can only be achieved by developing budgets that reflect integrated and balanced programs and staffing to implement these programs. Program priorities and budget information begin with you! Good stewardship also requires professionals from a wide range of disciplines working well together.

This Workshop offers you the opportunity to become an even better hydrologist — one that can and should play a vital role in helping the agency become a recognized global leader in Watershed Management.

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A Cross Section Of Procedures Used To Assess Cumulative Watershed Effects On Forest Lands In The U.S.

Walter F. Megahan[1]

Abstract.--Paper reviews the genesis of a cumulative effects program sponsored by the paper industry; reports on a survey taken to determine CWE procedures of federal and state agencies; and finally, synthesizes the data and reports findings and recommendations.

INTRODUCTION

The issue of cumulative watershed effects (CWE) has been implicit to concerns linking forests to downstream values for many years. Cumulative effects were explicitly defined in 1969 in the National Environmental Policy Act (NEPA) and again in 1971 when the Council on Environmental Quality (CEQ) provided an expanded definition of cumulative impact. Ambiguity of the terminology used by the CEQ to define cumulative effects resulted in considerable debate during the late 1970's and 1980's to refine the definition (Coates et al. 1979; Coates and Miller 1981; Geppert et al. 1984; O'Leary 1984). Although definitions vary, common elements are summarized and simplified in the definition presented by Reid (1991):

"... a cumulative effect is any environmental change influenced by a combination of land-use activities."

Following the direction of NEPA as well as subsequent direction in the National Forest Management Act, the U.S. Forest Service began developing methods to evaluate the cumulative effects of forest management practices as an integral part of forest planning activities. Other federal agencies such as the Bureau of Land Management and the Tennessee Valley Authority as well as the states of California, Oregon, Washington, Idaho and Montana are also actively developing procedures to evaluate CWE. Concern for CWE has also spread to Canada where an assessment procedure was developed for western British Columbia (Wilford 1987). Consultants have also become interested in developing CWE procedures (Klock 1985).

The forest products industry has also responded to the need to predict CWE by developing a Cumulative Effects Program under the direction of the National Council of the Paper Industry for Air and Stream Improvement (NCASI). The NCASI program is designed to develop accountable, defensible and reproducible methods to estimate CWE (NCASI 1992). One of the first tasks identified in the NCASI CWE program was to conduct an assessment of currently used CWE procedures. The objective was to evaluate these procedures in order to benefit from the knowledge and experience of others while attempting to avoid the pitfalls and to promote future coordination of efforts.

SURVEY OF CURRENT CWE ASSESSMENT PROCEDURES

The survey of current CWE assessment methods was carried out using a canvassing technique. A comprehensive survey form was developed to summarize information on a variety of topics including: the type of expertise used to conduct the analysis, an evaluation of how and where the assessment is used, the types of land uses evaluated, cooperation by other land owners, natural resource issues of concern, data requirements, and details of how watershed processes are evaluated.

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Copies of the form were sent to all groups or individuals known to be conducting CWE assessments on forest lands on an operational basis including: the nine U.S. Forest Service Regional Offices; the Bureau of Land Management in Oregon; the states of California, Oregon and Idaho; the Tennessee Valley Authority; the British Columbia Ministry of Forests and a private consultant. All correspondents were asked to participate even if their CWE procedure was in a developmental stage. In many instances, a general CWE procedure has been modified locally such as for individual national forests within a Forest Service region. A separate completed form was requested for each location where such modifications exist.

A total of 35 completed questionnaires were returned; 31 from the U.S. Forest Service; 1 from the Bureau of Land Management, 1 from the British Columbia Ministry of Forests; 1 from the state of Idaho and 1 from a private consultant. The number of National Forest (NF) units responding was 27, not 31. Three NFs returned more than one questionnaire. In two of the three cases, separate procedures are used to evaluate different things (eg. flood potential and erosion/sedimentation). In the other case, two different people completed and returned the form for the same procedure. Thus, the results of this study represent input from 31 separate groups who are using CWE assessments on an operational basis.

The following discussion is based on information provided on the questionnaires and on any additional information contained in guideline material supplied with some of the completed survey forms. CWE procedures are available in addition to those used by survey respondents but are not discussed here in order to maintain a common data base for comparing methods.

GENERAL CHARACTERISTICS OF CWE ASSESSMENTS

Location, Ownership and Watershed Size

Current emphasis in CWE is clearly centered in the western U.S. with 13 of the respondents from Oregon, 5 each from Washington and Idaho and individual responses from 7 other western states and Canada. Arkansas was the only state represented from the eastern U.S. With one exception, all of the procedures used in the U.S. were developed to evaluate CWE on federal or state owned lands and almost all of them (94 percent) are applied to mixed land ownerships within the analysis watersheds. However, only 27 percent of the analyses done on watersheds with mixed land ownerships involve the other land owners in their assessments. CWE assessment procedures for individual watersheds are normally designed to apply to a range in watershed sizes. Survey respondents reported large variations in watershed sizes ranging from 0.1 to 50 square miles for the smallest watershed size evaluated to 3 to 500 square miles for the largest watershed.

Procedure and Who Does it

Respondents categorized their procedures into three groups as: 1) a method to screen for hazardous situations (55 percent), 2) a qualitative assessment of watershed processes and responses (79 percent), and 3) a quantitative assessment of watershed processes and responses (56 percent). Almost all procedures were considered to be combinations of the three categories with 45 percent both screens and qualitative assessments, 33 percent both qualitative and quantitative assessments, and 6 percent in all three categories. Only 21 percent of the procedures were considered to be quantitative alone and 6 percent consisted of screening alone. The heavy emphasis on qualitative assessments suggests the need for expert input from technical specialists. This was the case in 88 percent of the responses and included the services of hydrologists, soil scientists and fishery biologists; the remaining 12 percent of the procedures are conducted by foresters.

Land Uses Evaluated

Types of land use activities evaluated vary. All forest managers were concerned with the effects of timber harvest and almost 80 percent indicated that roads were a major CWE issue. Following in decreasing order of importance were forest fires (61 percent), disturbances in the riparian zone (54 percent), and mining (21 percent). Agriculture and grazing were identified in 15 percent of the cases and a few other types of use such as ski areas, and insects and diseases were also identified.

CWE Issues of Concern

CWE issues of concern were identified for onsite and downstream locations. Onsite issues included soil compaction in 45 percent of the cases, both with respect to potential effects on overland flow runoff as well as concerns about site productivity. Wildlife issues appeared in 15 percent of the responses and usually reflected concerns about local threatened and endangered or big game species (excludes concerns about spotted owls). Aesthetics was a issue in 9 percent of the procedures. An opportunity to identify additional onsite concerns was provided in an "other" category and indicated that a surprising 45 percent of the respondents were concerned about erosion, presumably with respect to potential impacts on site productivity. The "other" category also indicated individual concerns about site regeneration and nutrient cycling.

Changes in sediment yields were the most prevalent downstream issue of concern and were identified at 70 percent of the locations. Channel condition ranked second at 60 percent followed by flood flows and fisheries at 52 percent and 48 percent respectively. Water yield was an issue in 45 percent of the cases. As might be expected, most of the concerns about water yield (73 percent) were confined to the dryer portions of the west in the states of Idaho, Montana, Arizona, New Mexico, and in the eastern portions of Washington and Oregon. Concerns about state water quality standards generated an interest in general water quality in 36 percent of the surveys and water temperature in 21 percent of the surveys. Aquatic habitat was an issue in 36 percent of the locations. Low flows were identified at only 2 locations for 6 percent of the total responses.

Threshold of Concern

Implicit in all CWE analyses is the need to define how much cumulative effect is allowable. This is most often treated in the existing CWE procedures by defining a "threshold of concern" or TOC. In some cases, the TOC defines a specific value that indicates significant impact and is used as an on-off switch for land use activities. This approach falls in the realm of "catastrophe theory" (Zeeman 1976) and implies a discontinuous response function with negligible adverse impact below the TOC and major impact above it. Such situations do occur in nature but are relatively rare, for example, the occurrence of a shallow debris-type landslide or possibly the point of breakup of the armor layer in a stream channel. Most often, the response function is continuous and the definition of the point of significant impact or TOC becomes much more difficult. Recognizing this, many CWE procedures treat the TOC as a "yellow flag" that indicates the need for a more detailed CWE assessment.

A total of 37 responses regarding the nature of TOCs used in individual locations were received in the CWE survey. This total exceeds the total number of locations sampled and indicates that more than one TOC is used at some locations. Seventeen of the TOCs were established on the basis of some measure of watershed slope disturbance; one consisted of a weighted index of several land use activities, 12 were based on measures of vegetation disturbance such as percent cutover or equivalent clearcut area, 2 were based on an equivalent road area index, and 2 were based on measures of soil compaction. The soil compaction TOCs were directed at soil productivity issues; all the others were designed to protect downstream values based on empirical relationships between slope disturbance and downstream responses. Another 16 TOCs were based directly on downstream responses including 7 that were dependent on average annual sediment yields, 6 based on channel condition, 2 based on fish habitat factors, and one directed at a state water quality standard. In three instances, respondents indicated that a "TOC" was established by comparing alternative land management activities within a given basin.

TYPES OF CWE PROCEDURES

Procedures used for CWE analysis include one or more of the following: 1) monitoring, 2) screening, 3) CWE indices, 4) interdisciplinary teams, and 5) assessments of changing geomorphic processes. Most procedures define a TOC to help define whether CWE goals are attained. Brief descriptions of existing procedures are presented here, more in-depth discussion will be provided in a forthcoming NCASI Technical Bulletin (1992).

Monitoring

Monitoring alone is used on the Winema NF to assess CWE. Monitoring elements dealing with CWE include fish habitat, soil, riparian zones, and water. Water elements are evaluated in terms of BMP implementation (are BMPs properly applied and perform-

ing as expected) and effectiveness (water quality sampling, channel morphology and an annual accumulation of land use activities on the watershed). A TOC is established for each monitoring element.

Screening

Screens consist of a series of questions in a checklist designed to assess the extent of onsite activities, evaluate onsite and downstream hazards and risks, and check for the existence of CWEs either onsite or at downstream locations. Screens provide a comprehensive but low resolution evaluation of all potential CWEs and are usually designed to be conducted by personnel other than earth scientists (usually foresters). Accordingly, a more detailed level of analysis that requires the input of technical specialists is required in high hazard or risk situations or when CWEs are identified. Examples of screening procedures include those developed by the British Columbia Ministry of Forests and Lands, and region three of the US Forest Service.

CWE Indices

CWE indices utilize a series of ratings for one or more of the important factors influencing the geomorphic performance of a watershed. Ratings are mathematically combined to provide an assessment of present watershed condition and sensitivity to use. Some procedure is designed to define a TOC based on potential impacts to beneficial uses that provides a basis of comparison for alternative land use scenarios. Examples of CWE indices include the KWCEA model (Klock 1985), a watershed sensitivity index developed by the Tongass NF in Alaska (McCorison et al. 1989), and the watershed condition index used by the Bureau of Land Management in Oregon.

Interdisciplinary Teams

The interdisciplinary team approach utilizes a group of technical specialists to evaluate watershed conditions and processes, and assess the status of downstream channel conditions and beneficial uses. Projected effects of alternative land use activities are then compared to arrive at some optimum mix of future land uses. The Mount Baker-Snoqualmie NF used an IDT procedure to assess CWE for their forest management plan.

Equivalent Road Area Procedure

The ERA procedure contains elements of the screening, CWE index and interdisclipinary team approaches described above. Survey respondents using adaptations of the ERA procedure include the Malheur and Rogue River NF in Oregon and the Eldorado NF in California. Coburn (1989) provides a description of the procedure used on the Eldorado National Forest that includes four phases: 1) an assessment of watershed sensitivity based on runoff potential, soil erodibility, slope gradient, mass erosion potential and other factors; 2) development of a land disturbance history of the watershed based on a table of ERA coefficients that vary by type of disturbance and time since disturbance; 3) field investigation of channel conditions; and 4) the establishment of a threshold of concern using outputs from phases 1,2 and 3. ERA values at or near threshold indicate "yellow flags" that signal the need for more in-depth watershed assessment.

Approaches to Assess Geomorphic Responses

Approaches designed to assess geomorphic responses are the most common type of CWE assessment procedures with use at 22 different locations. These approaches are based on the assumption that forest management activities affect one or more basic geomorphic processes including streamflow volume and rate, erosion, sediment, and water temperature. All procedures included within this group provide actual predictions of geomorphic responses including changes in streamflow, erosion, sediment yield, and water temperature.

1) **Equivalent Clearcut Area (ECA)** - The ECA procedure was developed by the U.S. Forest Service to provide estimates of changes in streamflow following timber harvest in the snow zone of the northern Rocky Mountains (U.S. Forest Service 1974; Galbraith 1975). Streamflow changes vary by elevation and sometimes soil depth and are based on the percentage of the watershed area in an "equivalent clearcut state". Water yield increases are at a maximum at the time of clearcutting and vary by elevation and sometimes soil depth. Tables are provided to adjust area of partial cuts to

equivalent clearcut areas and to account for hydrologic recovery over time based on forest habitat types. Monthly water yields are adjusted proportional to the predicted changes in annual water yield to estimate changes in springtime snowmelt flood peaks and the duration of flow at or above 75 percent of the precutting monthly peak flow. Excessive changes in peak flows or the duration of flows at or above 75 percent of the precutting peak flow are assumed to increase channel erosion and cause decreased channel stability. Local experience and observations of changes in stream channel stability associated with different levels of streamflow increases are used to define "allowable" changes in streamflow.

2) **Aggregate Recovery Percentage** - The Aggregate Recovery Percentage (ARP) and its derivatives were developed to provide a means to index the effects of forest cutting on peak flows resulting from rain-on-snow events in the Cascade Range in Oregon and Washington. Excessive increases in peak flows are assumed to result in unacceptable levels of channel erosion and cause damage to aquatic habitat conditions. The ARP provides an estimate of the percentage of the watershed area that has reached "hydrologic recovery" where hydrologic recovery is defined on the basis of stand regrowth in terms of one or more of age, height, canopy cover or diameter. For example, hydrologic recovery on the Mount Hood NF is defined as a stand with a crown closure of 70 percent and trees with an average diameter breast high of 8 inches. Other NFs using some type of ARP procedure include the Willamette, Umpqua, Rogue River and Gifford Pinchot.

3) **Runoff Curve Number Procedure** - The runoff curve number (RCN) procedure was originally developed by the U.S. Department of Agriculture, Soil Conservation Service in order to estimate storm runoff hydrographs for watershed management planning purposes as directed in the 1954 Watershed Protection and Flood Prevention Act (PL 83-566). Storm runoff volume and peak flows are predicted on the basis of watershed size, shape, time of concentration for flood flows, slope gradient, and hydrologic properties of soil-cover complexes. The Manti-Lasal NF uses the RCN method to estimate flood runoff for alternative forest and range management activities for various return interval storm events.

4) **Universal Soil Loss Equation** - The Universal Soil Loss Equation (USLE) was developed by Wischmeier and Smith (1978) to provide an estimate of average annual erosion from sheet and rill erosion on agricultural lands. Subsequent work by Dissmeyer and Foster (1981) and Renard et al. (1991) adapted the USLE to predict sheet and rill erosion on forest and rangelands. Versions of the USLE are being used on the Colville, Umatilla, Caribou, Challis, Manti-Lasal and Ouchita NFs located in the states of Washington, Oregon, Idaho, Utah and Arkansas. Erosion predictions are made for various kinds of soil disturbing activities including timber harvest, site preparation, fire, mining, agriculture, roads and grazing. In some cases, estimates of sediment delivery to channels are made as well as downstream sediment delivery to provide estimates of average annual sediment yields.

5) **Level 1 Stability Analysis - Level 1 Stability** Analysis (LISA) provides a means to evaluate the probability of occurrence of shallow landslides on forested slopes (Hammond et al. 1992). LISA is used primarily as a tool to compare landform stability and to estimate the relative decrease in stability of a landform caused by timber harvest. LISA uses the infinite slope stability model to evaluate the factor of safety against failure based on specified soil, groundwater, slope gradient and vegetation conditions. The Olympic, Willamette, and Gifford-Pinchot NFs in Washington and Oregon use LISA as an integral part of their CWE assessment process.

6) **R1-R4 procedure** - The R1-R4 procedure was developed jointly by Regions 1 and 4 of the U.S. Forest Service to estimate average annual sediment yields from forested watersheds in the "natural" or undisturbed state and with various types of disturbances (Cline et al. 1981). The method has been recently updated in a computerized form and included with the ECA procedure described above (U.S. Forest Service 1991). Disturbances considered include timber harvest, roads and fire. For each type of disturbance, erosion rates are maximum immediately after disturbance and decrease over time. Various types of mitigation measures to reduce surface erosion rates are included in the road erosion module of the procedure. The procedure includes modules to estimate mass and surface erosion, delivery of eroded material to channels and down-channel delivery of sediment. Most applications of the procedure utilize the landscape stratification system of Wertz and Arnold (1972) to delineate areal variations in erosion and slope sediment delivery rates.
7) **Brown's Water Temperature Model** - The Willowa-Whitman and Gifford Pinchot NFs in Oregon and Washington respectively are using the Brown temperature model (Brown 1970,1972) to evaluate the effects of vegetation removal in the riparian zone on water temperature. Increases in potential water temperature are determined as a function of stream surface area exposed to direct solar radiation, the net solar radiation load and stream discharge.

DISCUSSION AND CONCLUSIONS

Assessment of the Survey Approach

An alternative approach would have been to gather copies of the guidelines used for the various CWE assessments and summarize the required information to the extent possible from the guidelines. Such an approach would have make it impossible to answer some of the survey questions, constrained the size of the sample (no guidelines are available in some cases), limited the consistency of comparisons, and restricted the opportunity to benefit from the experience of the user-developers.

Some problems did surface using the survey approach. The most obvious was a lack of response from known users of CWE procedures. For instance, the state of California is making widespread use of a CWE assessment procedure but did not respond to the survey. In some cases, it was clear that respondents misinterpreted the questions or the questions did not fit the procedures being used. In another case, two different people responded to the questionnaire from the same national forest. Differences in the answers to some of the same questions clearly illustrated differences of interpretation by individuals. In spite of a request to have the person most familiar with the procedure fill out the survey form, statements such as "I don't know" in a few instances indicated that this was not always the case. Finally, the cover letter sent out with each survey included a request to include a copy of any guidelines or other documentation used for each procedure. The intent was that the information supplied on the survey forms could be checked for consistency against the written guideline material. Unfortunately, many respondents did not supply any written material, in some cases because guidelines do not exist.

OVERVIEW OF SURVEY RESULTS

In spite of the problems with the survey, some generalizations are apparent as follows:

- In some instances, procedures used at individual locations are undoubtedly appropriate for that specific situation. However, the survey clearly illustrates a glaring fragmentation of effort as indicated by a lack of structure and consistency of CWE assessments when comparing procedures between locations, even in situations where site conditions and forest management issues are very similar.
- Scope of assessments vary greatly from broad screens to models of assumed geomorphic responses. The broad screen approach is useful for addressing all potential CWEs but provides little guidance for management activities. The modeling approach assumes the existence of a specific geomorphic responses but overlooks other

types of CWEs and may incorrectly identify cause and effect mechanisms that can lead to unnecessary environmental damages or constraints on land use.

- Many CWE assessment procedures utilize indices that are difficult to interpret and apply elsewhere or assume relationships between site disturbance and downstream response that may or may not be true for a given watershed. In either case, the procedures can not be validated by field monitoring.
- In many cases, TOC values are adopted even though a true threshold in the mathematical sense doesn't exist. Elsewhere, TOC values are treated as "yellow flags". The latter approach appears more reasonable in view of the difficulty in defining the TOC and the problems associated with the accuracy and precision of the monitoring that is often needed to assess TOC levels.
- CWE assessments are being conducted without benefit of written guidelines in some locations.
- No attempt is made to address the scientific uncertainty of CWE assessments. A corollary to this is that the scientific uncertainty of procedures could be reduced in many cases by specific research and development efforts directed at weak links in the procedures.

Where to from Here?

Based on the above, where do we go from here? Some generalizations are possible as follows:

1) Both screens and more detailed CWE assessment procedures have advantages but must be used together to maximize effectiveness. A tiered CWE evaluation approach is needed that incorporates both a screening level (level 1) and a more detailed assessment as needed (level 2). The level 1 screen should be designed to consider all possible CWEs, evaluate watershed hazards (sensitivity analysis) and risks (downstream water resource values), and provide some indication of the physical linkages between on-site land use and downstream effects (what might be causing the problem). Given high hazards and/or risks or an existing unacceptable CWE, the level 2 analysis is required to better define how onsite forest management activities actually link to downstream watershed values and could involve more field assessment and modeling.
2) A program designed to stratify broad regional differences in physical processes and to the extent possible, in CWE issues of concern, would be very useful for focussing CWE assessments between areas. Possible factors to consider might include stratifications of surface and mass erosion hazards, hydrologic regime, climatic regime, vegetation and regional CWE issues of concern. Such a stratification would provide a starting point for the screening process described in 1 above and would help to eliminate local fragmentation of effort.
3) To the extent possible, CWE assessments should be physically based and designed to link causes and effects. Assessments should be made in terms of measurable watershed responses so that monitoring can be designed to validate predictions.
4) Thresholds should be treated as "yellow flags" or, better yet, developed on a probabilistic basis that considers both the uncertainty involved in the predicted response occurring as well as the uncertainty involved in detecting the response.
5) All CWE assessment procedures must be accompanied by definitive guidelines.
6) A broad scale research and development program is needed to develop CWE assessment procedures and to fill knowledge gaps. The R and D effort should be coordinated among all groups concerned.

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Cumulative Watershed Effects In Mixed Ownership Drainages: The Montana Cumulative Watershed Effects Cooperative

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Abstract.--An effort to promote cooperative basin-wide planning for timber harvest in mixed ownership watersheds in Western Montana has been in place since 1987. The cooperative covers an area of 9 million acres. Participants in the cooperative effort include forest industry, land management agencies, regulators, and interested organizations. Progress has been made in exchanging harvest information, implementation of Best Management Practices, watershed modeling, development of a process for identification and verification of cumulative impacts, and problem resolution. Implementation of the process has been limited to one 1800 acre watershed. The effectiveness of the cooperative has been limited for several reasons, including lack of agreement on the cumulative effects threshold issue, lack of technical resources, and lack of clear objectives.

INTRODUCTION

This report describes an effort to cooperatively address the cumulative effects of timber harvest on mixed ownership watersheds in Montana. I will discuss:

1) Why the cooperative effort was initiated.
2) How the cooperative is designed to function.
3) The accomplishments of the cooperative.
4) Some of the problems encountered.

The origins of the Montana Cumulative Watershed Effects Cooperative (MCWEC) date back to 1984. At that time, cumulative watershed effects were becoming a significant factor in reducing timber harvest on government owned lands in western Montana. The USDA Forest Service (USFS), Bureau of Land Management (BLM), and the Montana Department of State Lands (DSL) were limiting activities to accommodate watershed concerns, the activities of other owners, and downstream beneficial uses.

Gary Brown, Montana State Forester, initiated discussion among forest landowners in order to:

1) Address cumulative effects caused by timber management.
2) To insure that all forest land owners share in the opportunity to harvest timber on their lands.

COOPERATIVE DEVELOPMENTS

In 1985, following a series of meetings with forest industry, land management agencies, and regulators, the participants in this effort accepted the following issue statement:

"Land management activities can alter the run-off characteristics of a watershed which can affect water quality."

This issue may have represented a big step for some members, but from a technical aspect, it has short-comings as an issue statement from which to develop a cooperative.

The landowners agreed to address the cumulative effects issue and the initial foundation was laid:

1) The area included in the cooperative is the northwest portion of the state, the primary area in Montana with government and industrial timberlands. It includes the

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mixed ownership drainages of the Lolo, Flathead, and Kootenai National Forests (NF) and adjoining lands. This includes about 9 million acres of government and industry lands.

2) Cooperators agreed to exchange information on proposed and existing timber harvest to facilitate watershed analysis.
3) Best Management Practices (BMPs) implementation is the first line of defense for water quality protection.
4) Develop a Memorandum of Understanding (MOU) to solidify the commitments. In 1987, the MOU was signed. The cooperators are:
    1) USFS -- Region 1
    2) BLM
    3) Montana DSL
    4) Champion International Corporation
    5) Plum Creek Timber Co.
    6) Montana Dept. of Health & Environmental Sciences -- Water Quality Bureau.
    7) Montana Dept. of Fish, Wildlife, and Parks
    8) Montana Dept. of Natural Resources and Conservation
    9) Montana Association of Conservation Districts
    10) Montana Wood Products Association
    11) Montana Logging Association

The leadership role of the cooperative was assigned to the State Forester. The first step was to compile (BMPs) from numerous sources into a standardized version. The second step was to initiate an information exchange for proposed and existing timber harvest. A computerized data base format was developed and each cooperator annually furnish proposed timber harvest information.

By 1988 it was evident that BMPs and information sharing were not adequate to address the cumulative effects issue. It was clear that a standard methodology for determining when cumulative effects have occurred or are imminent and a process for resolving conflicts were needed.

A Technical Committee was established to accomplish the objectives. This committee included a representative from the land owners and regulators in the Cooperative. Members are hydrologists, soil scientists, and fisheries biologists. The Technical Committee developed a methodology to address cumulative effects issues. This methodology was documented in a report titled "Process To Address Watershed Effects In Mixed Ownership Drainages" (MCWEC 1988).

The process involved a three phase methodology:

Phase 1. Mechanism to identify existing or imminent cumulative watershed effects.

Phase 2. Mechanism(s) to verify cumulative watershed effects.

Phase 3. Problem resolution.

Phase 1 - Problem Identification

Watershed modelling provides the basis for problem identification, but any indicator of watershed concern may be used. Model output is typically compared to recommended threshold values established based on watershed condition and beneficial uses. Field evaluation is an essential component of the process. Decisions are not made solely on the basis of watershed models. Each cooperator sets their own threshold value for the upper limit of disturbance allowed in a watershed. It is the recognized that each cooperator may prescribe a different threshold for the same drainage. Some landowners are willing to accept a higher level of risk than others.

When a Cooperator feels a prescribed threshold has been reached, that entity will notify other Cooperators for discussion and verification. Model results and other information used to document the situation are shared with all landowners.

Phase 2 - Problem Verification

It becomes the responsibility of the identifying Cooperator to **verify** the existence of a problem and **convince** other affected landowners that the concerns are legitimate. This process may include the following:

a. Silvicultural management historical review (past harvest, road construction, mitigating measures, current hydrologic status, etc.)
b. Water quality and quantity data; actual monitoring data where available.
c. Stream condition analysis which may include channel condition inventories, fish habitat surveys, channel substrate measurements, and cross-section analysis, etc.
d. General field observations (by Technical Committee and Managers).

Phase 3 - Problem Resolution

Following Phase 2, the party that initially identified the problem will organize a meeting between all affected parties. The objective of this meeting will be to develop a cooperative plan which protects water quality, as well as meeting the management objectives of all parties as nearly as possible. All participants agree to the following ground rules, which are patterned after rules developed for the state of Washington's Timber-Fish-Wildlife Process.

a. All parties recognize the legitimacy of the goals of other cooperators, and assume that their own goals will be similarly respected. Each Cooperator will give the same priority to solving the problems of others as they would give to solving their own.
b. Each party agrees to protect the other participants and the process politically within their organization and with the public.
c. All parties agree to make a conscientious effort to develop a consensus plan, and agree to be advocates for the completed plan.
d. All communications with the news media or other outside parties will be by agreement of the group. Everyone will be mindful of the impacts their public and private statements will have on the success of this effort. No participant will discuss the suggestions, comments, or ideas of another participant with the media or other non-participants.
e. Each party agrees to raise concerns as early as possible, and agrees to negotiate and evaluate alternative management options in good faith. All parties recognize that inflexibility or refusal to recognize the goals and needs of other parties will never produce positive results.
f. Any party may leave the process at any time, but only after explaining their reasons for leaving to the entire group and attempting to resolve the problem. All normal rights, remedies, and positions remain available if the Cooperative effort is unsuccessful.

The next step in the development of the Cooperative was to establish standard methods to use in the Verification process (Phase 2). The Technical Committee adopted a multi-tiered approach using the following techniques:

- Stream reach and channel stability rating procedure (Pfankuch 1978).
- Channel geometry (cross-section) measurement.
- Crest gauge
- Macro-invertebrate sampling.
- Photographic record of cross-section sites.
- Whitlock-Vibert box measure of fine sediment (Weshe et. al. 1989).
- Survey of BMP implementation and sediment sources.

This work is completed by Technical Committee members.

ACCOMPLISHMENTS OF THE COOPERATIVE

1. Information exchange regarding harvest activities.
2. Assisted in development of and improved implementation of BMPs.
3. The personal computer version of WATSED (USFS 1992) was developed by the USFS for use by the cooperative. WATSED is a cumulative watershed effects model that reports water yield and sediment yield increase due to land disturbance activities.
4. The MCWEC is funding two research projects at this time. They are:
   A. The evaluation of a channel stability index procedure, based on the dominant particle size in channel beds, to identify and classify channel susceptibility to increases in discharge. This is designed to be a verification of work that originated with Gordon Grant, explained in "Assessing Effects of Peak Flow Increases on Stream Channels: A

Rational Approach" (Grant 1987). This work is being done by Dr. Donald Potts from the University of Montana.

B. The subject of the second project is watershed threshold analysis. This is a three year project being conducted by Dr. Lee MacDonald of Colorado State University. The objectives of the study are:
   a. Evaluate the factors relating to timber harvest and related activities which cause increases in the size of peak stream flows.
   b. Develop criteria for determining the amount, degree, and type of impact attributable to peak flow increases.
   c. Better identify the peak flow increase thresholds to be used as planning tools for future timber harvest activities in northwestern Montana.

5. The three phase process has been completed for one 1800 acre watershed. After several years of modelling, field tours, monitoring, meetings, and deferral of timber harvest on government owned lands, industry agreed to defer harvest on several hundred acres while monitoring continues.

As noted, the Cooperative has made some accomplishments. However, in my opinion, the effort has not been as effective as it could be. This judgment is shared by the chairman of the Cooperative.

PROBLEMS AND THE FUTURE

In a letter and position paper sent to Cooperative members dated March 20, 1992, Gary Brown made the following statements: "The Cumulative Watershed Effects Cooperative has been touted as the answer to the cumulative effects issue for Montana. The Cooperative has been effective in only several isolated instances. The Cooperative may be counter-productive for the water resources of Montana if the existence of the Cooperative gives the impression that the forest landowners are effectively dealing with the issue. It is time to reform the cooperative...".

The Cooperative, as it is presently functioning, is not an effective tool for resolving cumulative watershed effects conflicts. It is primarily facilitating information exchange. I believe the Cooperative must go beyond information exchange and truly become the means to resolve land use conflicts resulting from cumulative watershed effects in mixed ownership drainages. Some of the public, media and cooperators believe the CWEC already functions as the means to resolve cumulative effects conflicts. I am convinced that is not the case. I believe the Cooperative will only become effective when every Cooperative member agrees to, and implements, the provisions that I have suggested in the (attached) position paper" (Brown 1992).

Recommendations for an Effective Cooperative

a. All proposed harvest activities will be analyzed for cumulative effects and the results shared with all Cooperative members with ownership in the watershed.
b. Accept threshold levels for the cumulative effects modelling process. Recognize that thresholds are flexible, but that there is a range of acceptability, based on the resources involved and site-specific conditions.
c. Accept a "majority rule" of professional judgement from the Cooperative's Technical Committee concerning watershed-specific threshold levels necessary to protect beneficial uses and avoid cumulative effects.
d. Allowable timber harvest in mixed-ownership watersheds should be pro-rated based on ownership.
e. Provide sufficient resources to allow adequate and timely evaluation of watershed condition (Brown 1992).

The Cooperative's progress have been limited for several reasons. The foremost is that the management of cumulative watershed effects and the accuracy of the models are fraught with scientific uncertainty. The impacts of cumulative effects are often subtle and difficult to document or recognize. Yet when cumulative effects are altering channel morphology or physical habitat, the appropriate level of activity has already been surpassed. Another reason is that

solutions to these complex issues have been assigned to a Technical Committee, members of which have a very limited amount of time and resources to devote to the process. In addition, the management objectives of private and public organizations are different. The private sector has been willing to accept a much higher level of risk than the public sector. Without agreement on thresholds, the ability to arrive at consensus is difficult.

Some members of the Cooperative require that damage from cumulative effects be demonstrated before changes in management are made. In spite of the shortcomings of watershed modelling and the scientific uncertainty of the cumulative effects issue, it is a mistake to mitigate for cumulative effects only when the damage is evident to the land managers eye. When cumulative effects are altering channel morphology or physical habitat, the appropriate level of activity has already been surpassed.

When scientific uncertainty is high, the distinction between science and management often blurs. Resource management decisions hang on the answers to questions that can be asked, but often not answered. Thus, either the scientist or managers must make a decision based on a combination of existing scientific knowledge, peppered with healthy portions of professional judgement, personal values, and on-the-ground interpretation. The decision making process becomes subjective and more characteristic of the political arena than the scientific method. The results is a decision that is controversial and subject to challenge (Schultz and Sihler 1990).

The resources needed to implement the procedures of the Cooperative are immense. Many months of work were dedicated to the single case where the Cooperative has seen the process through all three phases. One district on the Kootenai NF has over 30 third order mixed ownership watershed where threshold values are exceeded (Johnson 1991). That's enough work to keep a fleet of Technical Committees busy for years. Given the existing work load, it is very easy to recommend deferral, skip the cooperative's process, and look for somewhere else to harvest timber. This is generally how the agencies functioned before the cooperative.

Recommendations for Entering into Mixed-Ownership Watershed Cooperative

1) A fundamental building block of the effort should be agreement on the concept of a "threshold". Are thresholds tiered to a level of acceptable risk or a measure of watershed degradation?
2) Do not expect organizations with distinctly different objectives to easily arrive at consensus over matters that have the scientific uncertainty that the cumulative effects issue has.
3) Do not undertake a commitment such as the Cumulative Effects Cooperative as "other duties as assigned". It is a immense job and an in effective cooperative is worse than no cooperative at all.

The Cooperative is taking steps to improve its effectiveness. A new MOU is being drafted to better define the role of the cooperative. Resource managers have renewed their commitment to make more resources available to the Technical Committee. The Technical Committee plans to more clearly identify their objectives and time schedule to give a better indication of the commitment necessary for an effective cooperative.

The Montana Cumulative Effects Cooperative is a good concept and, if implemented, will benefit the water resources and the cooperators.

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Forest Service Role In Natural Resources Conservation Service (Soil Conservation Service) Watershed Programs

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Abstract.--The Forest Service provides technical assistance on forestry to the Natural Resources Conservation Service (Soil Conservation Service) in the Watershed Protection and Flood Prevention Programs. Four of the programs are discussed.

INTRODUCTION

The Watershed Protection and Flood Prevention Act, Public Law 83-566 (PL-566), authorizes the USDA to prevent damage from erosion, floodwater, and sediment in watersheds. Public Law 566 also allows the USDA to undertake measures in furthering the conservation, development, utilization, and disposal of water, or conservation and proper use of land resources.

The Act additionally defines its purpose to be watershed protection, flood prevention, agricultural water management (including drainage and irrigation), nonagricultural water management (including public recreation, municipal and industrial water supply), groundwater recharge, and conservation and proper use of land.

The Natural Resources Conservation Service (NRCS) formerly the Soil Conservation Service Watershed Protection and Flood Prevention Programs involve Forest Service (FS) assistance. The FS role and responsibilities are outlined in Memorandums of Understanding.

The Watershed Protection and Flood Prevention Programs include River Basin Studies, Public Law 566 Small Watershed Planning and Operations, Public Law 534 Flood Prevention projects, and the Emergency Watershed Protection Program. The FS is responsible for the forest land and range lands associated with the National Forest System, private lands, and state lands. Where FS involvement is appropriate, we become a member of a planning team and work to solve the identified water resource problems. The NRCS transfers funds to the FS for this work.

COOPERATIVE RIVER BASIN STUDIES

Cooperative River Basin Studies (CRBS) authorize the USDA to provide planning assistance to local, state, and federal governments. The purpose of these studies is to assist those governments in assessing water and other land resource problems, determine the extent of the problem, and formulate alternative plans which may include land treatment measures or structural and nonstructural measures that would solve an existing problem. These studies usually concentrate on a specific objective that is identified by the sponsoring group. The objectives usually include the formulation of a plan that may require inventories of the available resources and associated problems. The USDA assistance is provided through a Field Advisory Committee (FAC) composed of the NRCS, FS, the sponsors, and other interested groups or individuals. The NRCS usually chairs the FAC.

The process begins when a local sponsor requests assistance. The sponsor submits a written proposal to the State Conservationist who forwards it to the Chief of the NRCS. The proposal must explain the need for the study, the need for USDA participation, the state's responsibilities, and estimate the duration of the study and the funds that are needed by each agency involved in the study. The Chief then may authorize the study to proceed. Authorization will depend on the readiness of the requesting agency to begin the study, the significance of the problem, type, duration and costs of the study, and other conditions.

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Each CRBS is different and each NRCS state water resources staff is different in its application of the program.

Some CRBS may not have a forestry element, and the FS role may be that of an advisor to the FAC or a reviewer of the final assessment plan. However, the FS role in a CRBS is to be an equal partner in all efforts to assist the sponsors. FS personnel will assess any problems relating to forestry, such as road-building and silvicultural treatments, or recommend land treatments using forestry to solve a problem, such as riparian forest buffers between cropland and streams.

The final assessment plan of a CRBS will identify the causes of water-related problems, evaluate solutions, and make recommendations to the sponsors. From this point, the sponsors will either implement the solutions recommended in the final plan or ask for additional assistance.

PUBLIC LAW 83-566

As with the CRBS, a sponsor, usually a local government agency or a soil and water conservation district, will approach the NRCS for assistance in solving a water-related problem in its area. The NRCS will then provide guidance to the sponsor by making preliminary evaluations that determine whether assistance is warranted and then help in preparing the necessary applications.

During the planning stage of a watershed study, the FS will assist in the preparation of a plan-Environmental Impact Study (EIS) with the cooperation and assistance of the NRCS, local sponsors, the state division of forestry, and others. Investigations and field reviews are made to determine the extent of the watershed problems or needs, and then recommendations are made. The recommendations will consist of accelerated land treatment practices, such as land conversion to trees on highly erodible lands, and the technical assistance needed to carry out those practices. Recommendations are not limited to those eligible under PL-566, but also those available from other federal, state, and local sources.

Once the plan-EIS is agreed upon by the NRCS and the sponsors and the required review and approval process completed, the NRCS will provide financial and technical assistance to implement the plan. The watershed now becomes operational and the accomplishments are referred to as works of improvement (WOI).

The FS is responsible for administering the forestry aspects of the WOI either through the state division of forestry, soil and water conservation districts, or contractors. Funds from the NRCS are passed to the FS, who then passes the funds to the state or local group who will be implementing the WOI. In most cases, the state division of forestry implements the work on the state and private lands, while the FS implements the work on the public lands.

PUBLIC LAW 78-534 - FLOOD CONTROL ACT OF 1944

The Flood Control Act of 1944 gives the USDA responsibility in eleven selected watersheds for watershed planning and installation measures to reduce runoff and erosion and to slow streamflow. Both the FS and NRCS, along with assistance from other agencies within and outside the USDA, are responsible for carrying out the responsibilities.

Out of the original eleven watersheds, five are currently active and undergoing a phase out: Los Angeles and Santa Ynez Rivers, California; Trinity River, Texas; Washita River, Oklahoma and Texas; and Potomac River, Maryland, Pennsylvania, Virginia, and West Virginia.

The FS role is to administer the forestry aspects of WOI through either the National Forest System, as in the case of the Los Angeles and Santa Ynez, or through the state foresters, as in the remaining three flood projects. Even though the FS involvement has been limited to passing funds to the state foresters, occasions arise where the FS assists the NRCS in updating forestry plans in preparation for the phase out of the PL-534 program. The WOI elements of the forestry plans may be updated every five years or so to determine the changes and needs of accelerated forestry assistance within the sub-watersheds of the flood project areas. Once the plans are updated, the state forester, FS, and NRCS need to agree upon increases or decreases in funding to accomplish the WOI measures of the updated plan.

EMERGENCY WATERSHED PROTECTION

The Emergency Watershed Protection (EWP) program is under the authority of Section 403 of Title IV of the Agricultural Credit Act of 1978. The major objective of the program is to assist in relieving imminent hazards to life and property from flooding and other natural disasters that might cause impairment of a watershed. The program is used when the existing local, state, and federal programs do not provide adequate facilities and funds for immediate action.

The NRCS administers the program in their respective states. This includes all coordination with other agencies. Once the State Conservationist is notified of the emergency situation, he or she will authorize assistance. Funds are transferred to the FS at the Washington level for work to be installed by the FS or its cooperators.

The FS is responsible for administering EWP measures on National Forests and National Grasslands, on all forested or rangelands within National Forest boundaries, on lands outside the boundary administered under formal agreement, and on all other forested lands under state or private designation. Cooperative Forestry in Washington is responsible for FS participation in this program, as well as, coordination with the NRCS.

HYDROLOGIC UNITS

In 1989, Hydrologic Units (HU) were developed through the USDA Water Quality Initiative by the NRCS, Agricultural Stabilization and Conservation Service (ASCS), and Cooperative Extension Service (CES). The HUs discussed here should not be confused with the HUs initiated by the US Geologic Survey (USGS). The USGS program is currently mapping watersheds and assigning a hydrologic unit number to each.

The FS was not involved with HUs nationally because: 1) the appropriations came through the USDA rather than the Department of Interior, 2) there was a focus on agriculture chemicals, animal waste, ground water, and load reduction below the root zone, and 3) the nature and extent of ASCS, CES, and NRCS educational, technical, and financial assistance support.

By late 1989, the NRCS, ASCS and CES submitted Hydrologic Unit Water Quality Plans to the National Headquarters for its review. Thirty-seven HUs and eight demonstration areas were selected to receive funds for accelerated technical assistance in water quality planning for the period 1990-1992. Another thirty-seven HUs were selected for funding for the 1991-1993 implementation period.

The FS role is much the same as in PL-566. With the aid of service foresters, NRCS personnel, and others, the Forest Service determines if there are forestry-related problems in the watershed, and if so, devises solutions to the problems. Otherwise, the Forest Service representative will recommend forestry as a solution to a water quality problem, such as planting forest buffers along streams or excluding cattle from woodlands.

Once the problems are ascertained and solutions and alternatives formulated, the HU Area Plan may be implemented. But unlike PL-566 where the NRCS provides the funding for all implementation measures and works of improvement, the other local, state, and federal agencies involved in the planning process must provide their own funds to implement their parts of the HU Plan. Because the FS does not readily have funding to accelerate activities in a HU, creative ways to implement the forestry elements of the HU Plan are needed. Usually, funding is sought to provide technical assistance dollars to hire a forester for the HU. The forester then provides technical assistance to landowners who are involved with various forestry and related incentive programs that accomplish recommendations made in the forestry section of the HU Plan.

SUMMARY

The FS has the leadership role for forestry in the USDA. Providing technical assistance to the NRCS is one of the ways we fulfill this obligation. The FS continues to assist the NRCS in all water-quality initiatives regardless of whether those initiatives are within the USDA or outside. The FS is an equal partner in most aspects of planning, and is responsible for the administration of forestry measures agreed upon during the planning phase of the initiatives.

Standard Fish Habitat Inventory Procedures and Potential Management Applications for the Intermountain West

C. Kerry Overton[1]

Abstract.--The Intermountain Fish Research Work Unit took on the task of developing and evaluating a standard core set of fish habitat inventory parameters and procedures for the U. S. Forest Service (USFS) Northern (R1) and Intermountain (R4) Regions. The lack of accepted standardized procedures for describing fish habitat in the Intermountain West has hampered the linking of research information with forest inventory data bases; prevented data comparisons between watersheds; confused and frustrated entry-level biologists faced with sorting out a myriad of procedures, methods, and inconsistent forest and district data bases; left few established long-term habitat data bases; and slowed the development and transfer of new management technologies and tools. The combination of all of the above factors has confounded the efforts to understand the relations between watershed, habitat, and fish. Standardizing fish habitat inventory parameters and procedures would facilitate widespread information exchange and the development of management applications and technical tools that could be applied between and throughout each region. Standardization is essential in linking and using corporate databases, decision support systems, and Geographical Information Systems (GIS). This paper will outline the proposed R1/R4 standard core set of habitat inventory parameters, provide a list of potential management applications possible with a common database, and provide some examples of current management uses of the inventory data.

INTRODUCTION

USFS fishery biologists are required to assess the risk of habitat degradation resulting from land-use alternatives. This requires a knowledge of existing habitat quantity and condition, the understanding of land-use effects on habitat, and the critical habitat requirements of the fish. Often, this information base is not available or requires considerable effort to find, organize, and analyze. This process of data compilation and analysis has been difficult because of the variety of parameters and procedures that have been used and because of the subjective and non-repeatable nature of many data collection methods.

Standardized USFS inventories have been advocated since the passage of the Multiple Use and Sustained Yield Act of 1960 (P. L. 86-517) and the Forest and Rangeland Renewable Resources Planning Act of 1974 (P. L. 93-452). The purpose of a national symposium in 1977 was to progress toward common data structures and analytical procedures among researchers, the conservation community, and resource managers (USFWS 1978). In 1960, the USFS Intermountain Region developed a transect method to provide a systematic and uniform approach to the

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inventory of aquatic habitat and the display of the resulting data (Collotzi and Dunham 1978). Platts et al. (1983) advocated the standardization of measurement techniques to make it possible to compare information and study results from area to area and to evaluate information on a uniform basis. The USFS Columbia Basin Anadromous Fish Policy and Implementation Guidelines (CBAFPIG) direct Columbia Basin Forests to have comparable information within sub-basins to identify existing aquatic and riparian conditions, identify factors limiting the productive capabilities of habitats, measure attainment of or progress toward Desired Future Conditions (DFCs), assess cumulative effects, and refine DFC numeric values (USFS 1991). It will also be important to establish standardized database structures for the incoming inventory data; such structures will facilitate the development of GIS layers on all geographic scales. In the future, these layers could be made widely accessible through the 615-Project (the USFS Corporate Database system), of which GIS is a part.

At the project level, a common set of habitat parameters would assist forest and district biologists in completing project and watershed limiting factor analysis and risk assessments. Entering these parameters into a suitable database and developing a database management system (DBMS) for use on the District level would allow region-wide information exchange, common training in procedures and in hardware and software use, and development of standard analysis formats (limiting factor assessment, risk assessment, statistical procedures) and standardized reports. It would also assist in the development and training of new biologists. Inventory databases, population and habitat research information, and physical and biological models could be combined to build a decision support system that would allow users to access and integrate data, models, and other research information, and summarize the results.

The objectives of this paper are to: 1) describe the proposed R1/R4 fish habitat inventory parameters, 2) list the developing management applications, and 3) provide examples of current management applications.

HABITAT INVENTORY PARAMETERS AND PROCEDURES

The goal was to develop quantifiable, repeatable, and affordable habitat inventory parameters and procedures that seasonal field crews could use with limited experience and minimal training. Table 1 lists the standard core set of parameters being proposed for describing the habitat structure of streams in the Intermountain West.

The inventory procedures are based on the classification of habitat types that describe the pool-riffle structure of a stream. Habitat types were first described by Bisson et al. (1981) to assist in identifying the interactions of fish with their habitats in small mountain streams; they were later modified by others to characterize habitat for different species across a wide range of streams (Bozek and Rahel 1991; Hankin and Reeves 1988; Kozel 1987; Lobb and Orth 1991; McCain et al. 1990; Modde et al. 1991). Habitat types are distinguished from each other based on fluvial geomorphic descriptors (e.g., flow patterns, stream energy, channel morphology) that have biological relevance to fish (Bisson 1981; Hawkins et al., in review). A hierarchical classification system is used to stratify the habitat types within slow water and fast water categories (Figure 1).

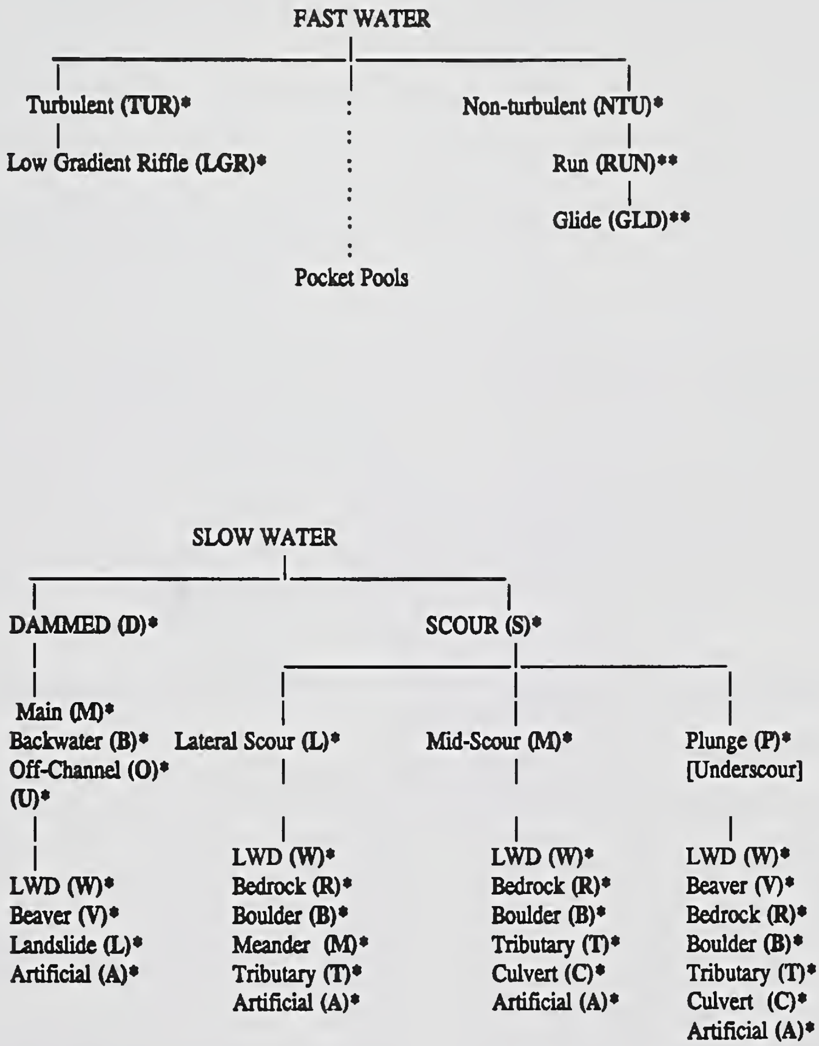
The R1/R4 measured parameters for characterizing individual habitat types were developed through a review of existing USFS Regional Inventory Procedural Handbooks, formal and informal contacts with forest and district biologists, field trials, inventory crew member interviews, inventory contract inspectors, and experience. To obtain quality data (i.e. accurate, consistent, and repeatable results), management utility (LMP, NEPA assessments, land-use effects indicators, project design), and cost-effectiveness (quality and utility vs. effort), an attempt has been made to keep procedures straightforward, to eliminate subjective and observer-biased parameters, to prevent hazardous and rigorous data collection techniques, and to obtain a survey rate of at least one mile per day. Evaluation of inventory parameters and procedures will extend indefinitely to ensure continued state-of-the-art development and management utility.

Table 1. Standard fish habitat inventory parameters for characterizing Intermountain West fish habitats.

Field Measured Parameters	Calculated Habitat Type Descriptors
1. Channel Type (Rosgen Gross Scale)*	1. Habitat Type Dimensions
2. Habitat Types (Hierarchical Scale)	- area
- fast vs. slow	- volume
- turbulent vs. non-turbulent	2. Pool Type Dimensions
- dammed vs. scoured	- residual max-depth
- channel & scour position	- residual pool volume
- formative feature	3. Width/Depth Ratio/Index
3. Habitat Type Dimensions	4. Large Woody Debris
- length, width, depth	- size class (length & diameter)
- max-depth, crest depth (pools)	- volume
4. Pocket Pool Number, Mean Depth	5. Habitat Diversity
5. Surface Fines (LGR's & pool tails)	6. Pool Complexity
6. Substrate Composition	7. Fish Data
7. Riparian Complex	- relative abundance (fish/area)
8. Large Woody Debris	- fish distribution
- number	- habitat utilization index
- dimensions	
9. Bank Condition	
- length stable vs. unstable	
- length vegetated vs. unvegetated	
- length undercut	
10. Wetted Channel Shape	
11. Temperature	
12. Photo Points	
13. Fish Species, Size Classes	
14. Comments	

* Rosgen, 1985

Figure 1. Hierarchical breakdown for fast water and slow water habitat types using the R1/R4 standard habitat inventory procedures.



(*) Habitat codes to be used in the field form.

Habitat Type Classification

Past evaluations of habitat typing based inventories have indicated that field technicians have problems in naming habitat types and in defining their upstream and downstream boundaries. The following procedures address this problem:

A) The R1/R4 habitat type classification system (Figure 1) has eliminated or made optional those habitat types that are hard to recognize. For example, fast water habitat types that were consistently misnamed (e.g., glide vs. run) can be lumped up to the next level - non-turbulent. Low gradient riffles are to be classified as individual habitat types, because of their biological importance (e.g., spawning, rearing, and invertebrate production) and as potential sites for gaining insight into the relation between substrate composition, bedload movement (sediment and water yield), and local and cumulative management effects.

B) A hierarchical key is used to identify the habitat types. For slow water habitat types, for example, the pools are first viewed as dam or scour formed. The second step is to determine the position of the scour (mid-channel, lateral, or plunge) or dam (main channel, backwater, or off-channel), and the third step is to identify what is directing the scour (large woody debris, bedrock, boulders, entrance of a tributary, a culvert, or an artificial structure) or causing the dam (large woody debris, beaver activity, landslide debris, or an artificial structure). See Figure 1 for a schematic presentation. Slow water habitat types are categorized in the most detail because of their biological significance; critical habitat research is indicating the importance of different pool types for rearing and overwintering of salmonids.

C) To help ensure data quality, a training manual and training stream will be used for teaching and testing field technicians.

POTENTIAL MANAGEMENT APPLICATIONS

A region-wide standardized database will facilitate the development and evaluation of management applications and tools; it will also provide one piece of a DBMS that can help streamline common management tasks and help solve complex management problems. Table 2 lists INT's potential management applications and technical tools and their developmental status. The list was formulated by assessing biologist needs, by evaluating NEPA and Biological Evaluation (BE) data requirements, and through investigations of new and evolving technologies (Aronoff 1989; GIS World 1991; Lunettia et al. 1991; Rauscher and Johnson 1991).

Habitat types will be the common denominator for linking management applications. Watershed and channel scale descriptors are being investigated as possible stratifying levels for habitat typing data; they may also provide links to help gain understanding of the interactions between watershed condition, channel structure, habitat, and fish.

MANAGEMENT APPLICATION EXAMPLES

Four field projects were initiated in May 1991 to evaluate the cost-effectiveness of the inventory parameters and procedures and the management utility of the inventory data. The fifth project is the development of the DBMS for storing and retrieving inventory data. The following are brief descriptions of these individual projects.

Desired Future Conditions

Thirteen wilderness stream reaches consisting of B-wooded, C-wooded, and C-meadow channel types were surveyed to evaluate the habitat parameters for use as DFC metrics and templates. Figure 2 displays an example of parameters being evaluated as DFC templates for selected wilderness streams with C channel type and wooded landcover. These DFC parameter summaries will be compared to like channel-landcover types of managed streams to determine if differences exist. These comparisons will assist in determining the existing aquatic conditions, general stream health, management effects, and display physical habitat potential of managed streams.

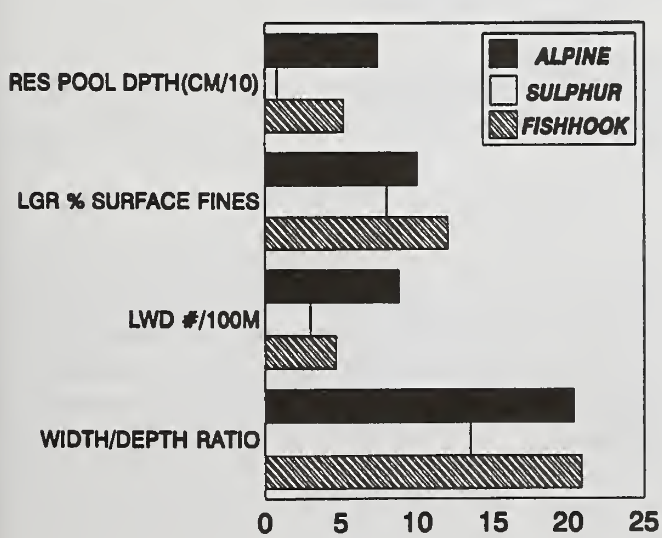
Anadromous Fish Habitat Summaries

Three hundred miles of Salmon River Basin streams were surveyed using the inventory and fish sampling procedures to determine parameter and procedures clarity from the point of view of the field crews, to determine cost per mile, and to satisfy the management requirements of the CBAFPIG. This data set will be compared with DFC templates and will be used to determine what parameters were related to management activities. Table 3 summarizes inventory parameter and procedure modifications based on problems encountered by crews and data processing (entry and proofing) personnel. In general, crews had problems with all parameters that were either subjective in nature or required experience and background in understanding channel processes (e.g., bankfull channel measurements); knowledge of management effects on banks and riparian communities (e.g., bank stability, R4 Riparian Greenline species identification and woody regeneration measurements); or experience in fish habitat relationships (e.g., pool cover recognition and classification).

Table 2. List of developing management support tools that are linked to the hierarchical habitat typing scheme.

Management Applications/Tools	Developmental Status (Planned Completion Date)
DBMS Canned Summary Tables	90% complete, currently debugging, dBase IV platform (Summer 92)
Oracle DBMS	software purchase - dovetail dBase IV structure (Fall 92)
Menu Driven DBMS Applications	40% complete (first version - Winter 92)
GIS - Habitat Data Layers	software, hardware, personnel, dataset acquired (Fall 92)
GIS - Fish Distribution Data Layers	software, hardware, personnel, dataset acquired (Fall 92)
GIS - Resource/Management Layers	coordinating development of dataset with Payette NF (??)
Watershed Scale Clustering	proposal method determined, coordinating with USGS (??)
Watershed/Channel Scale Disturbance	evaluating existing procedures, trial dataset available (??)
Standardized Analysis Formats	includes data summary, data comparisons, statistical analysis
- Timber	trial dataset collected, analysis started (Fall 92)
- Grazing	trial dataset collected, analysis started (Fall 92)
Standardized Monitoring Procedures	includes design, statistical procedures, new tools, videography, GIS
- Timber	have trial dataset. (design - Summer 92)
- Grazing	have trial dataset. (design - Summer 92)
Decision Support System	acquired software, personnel, design on the drawing board (??)
FHR Research Database	Chinook, Steelhead, Cutthroat, Bull trout critical habitat research in progress
Smolt Capability Index	drawing board, dataset available to draw from
Desired Future Condition Templates	dataset for 13 wilderness stream reaches collected, 80% complete (Fall 92)
Population Dynamic Models	drawing board, datasets available for initial evaluation (??)
Sustained Ecological System Approaches	drawing board, potential links being investigated(??)

Figure 2. Examples of habitat parameters for C-Wooded DFC streams (from Pisano and Overton, in preparation).



Timber Harvest Example

A paired watershed study comprising of Boulder Creek, a timber harvested watershed, and Rapid River (Payette NF), an undisturbed watershed, was initiated; 1) to determine if the habitat parameters and measurement procedures would detect differences between a timber harvested and an unharvested watershed; 2) to compare calibration results obtained using several different sampling frequencies (number of measured habitat type units vs. number of estimated units (note that different sampling frequencies require different field efforts and hence result in different costs); 3) to provide a data set for developing fish habitat and fish distribution GIS map layers to link to GIS map layers describing watershed and streamside management activities; and 4) to provide data for constructing and evaluat-

Table 3. Modifications in habitat inventory parameters resulting from evluation of the 1991 field data.

Parameter	Modification	Reason For Modification:
1. Channel Type	Same -	Rosgen gross scale classification (A,B,C)
2. Habitat Typing - Fast Water	Modify -	Use hierarchical scheme to assist in classifying habitat types.
- Turbulent vs Non-Turbulent	Modify -	Record only LGR & STP under Turbulent. Lack of crew consistency in crew recognition of other fast water habitat types.
- Slow Water	Modify -	Pools broken out by type (dammed vs scour), scour position and formative feature.
3. Habitat Type Dimensions - Length, width, depth	Modify -	Measure everything. Add figure to help determine beginning and ending points of habitat types.
4. Surface Fines	Modify -	Estimate only. Poor correlation between measured and estimated data. Optional surface fines grid.
5. Pool Complexity	Modify -	Working on pool complexity index from measured pool data. Snorkel crew will measure.
6. Wetted Channel Shape	Modify -	Evaluating the procedures for sampling wetted channel shape. May need to target this measurement at specific habitat types.
7. Substrate Composition (Wolman, 1954)	Modify -	Drop estimates and increase the number of measured sample units (Wolman Pebble Count).
8. Bank Stability	Modify -	Needs evaluation. Subjective data and poor consistency in crew recognition.
9. Bank Shape	Modify -	Drop bank shapes except for determining length of bank undercut. Bank shapes are subjective with poor consistency in crew recognition.
10. Bankfull Channel Dimensions - Width, length - Max-Depth, shore Depth	Drop -	Drop this measurement as an inventory parameter. Poor consistency in crew recognition.
11. Bankfull Channel Shape	Drop -	Drop this measurement as a inventory parameter. Poor consistency in crew recognition.
12. Large Woody Debris Count	Same -	Count of single pieces, aggregates, and root wads.
13. Large Woody Debris Dimensions	Same -	Estimated length, diameter, and volume.
14. Water Temperature	Modify -	Increase smpling frequency and establish permanent stations.
15. Gradient	Modify -	Determined from contour maps or DEM's.
16. Discharge	Drop -	Use surrogate for comparison (i.e.; Residual Max Depth).
17. Fish Count	Modify -	Need to evaluate sampling frequency.
18. Riparian Complex	Modify -	Drop Greenline and woody species regeneration measurements as an inventory parameter. Current procedures are not representative, are time consuming, with poor crew recognition. Replace by characterizing dominant and subdominant vegetation for every 10th habitat type.

ing habitat based fish dynamics models. Figure 3 and figure 4 are examples of large woody debris data comparisons between the two watersheds.

Cattle Grazing Example

Silver King Creek (Toiyabe NF), a cattle grazed stream that included exclosures, was used to determine first if the inventory parameters would detect the effects of cattle grazing and second how the survey information could be used in designing a long-term monitoring program. Figure 5 is an example of habitat inventory parameters that showed differences between the grazed and exclosure sections of Silver King Creek.

A monitoring strategy based on randomly selected dominant habitat types (e.g., low gradient riffles [LGR], lateral scour pools meander formed [LS7]), and habitat type attributes that were indicated as different between grazed stream sections, and exclosures (Figure 5) and known critical habitats of fish (e.g., pools, depth, substrate, cover), will be implemented to monitor change from year to year, and to develop relationships between range utiliza-

Figure 3. Differences in the number of large woody debris single pieces by diameter class for Boulder Creek (disturbed) and Rapid River (undisturbed) (From Radko and Overton, in preparation).

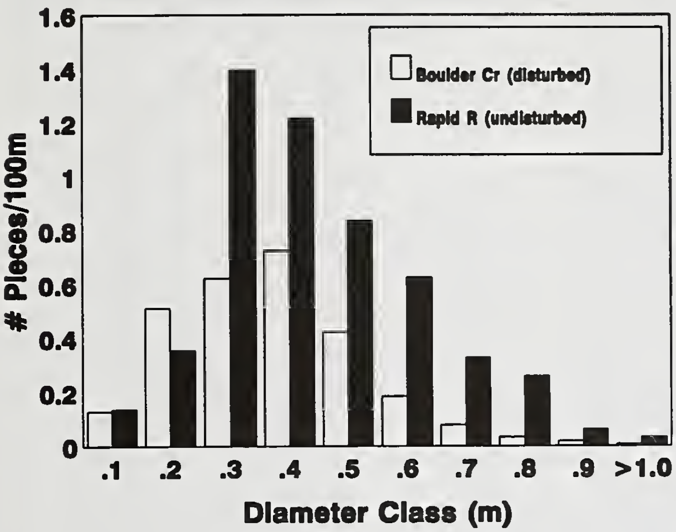


Figure 4. Differences in average length vs. diameter class for single pieces of large woody debris in Boulder Creek (disturbed) and Rapid River (undistrubed) (From Radko and Overton, in preparation).

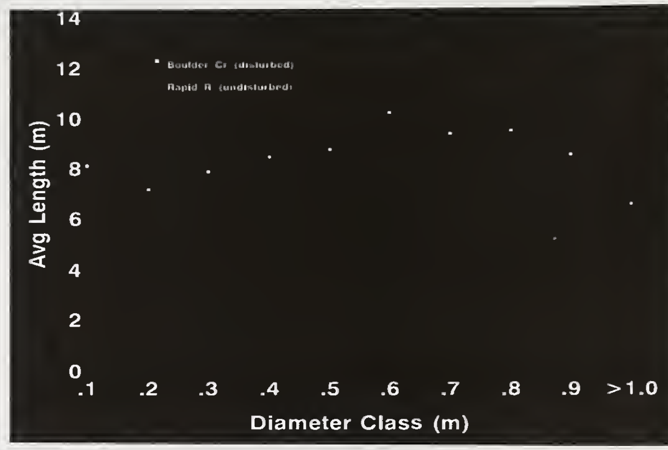
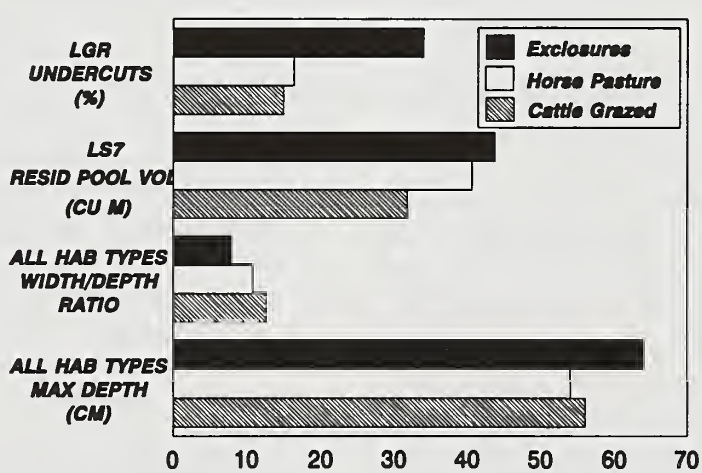


Figure 5. Differences in the habitat parameters between cattle grazed, horse pasture and exlosures in stream sections of Silver King Creek (from Pisano and Overton, in preparation).



tion parameters and habitat type parameters. This information base has the potential to assist in evaluating different grazing strategies and help identify key parameters to determine the direction fish habitat is heading - degrading, maintaining, or improving. Database Management System. A DBMS is being developed to enter, store, manipulate, summarize, and retrieve the inventory data. This system will be used as the framework for spatial analysis with GIS and for development of a decision support system; it is currently being evaluated and refined. The current DBMS contains data entry and editing routines, a simple linear regression program, a data calibration routine that corrects visually estimated data using measured data, and tables summarizing habitat data. Table 4 is an example of summarized data output for pools.

Table 4. Example output of the habitat inventory database management system for summarizing pool data (Boulder Creek, 1991).

Hab Type	Total No.	Total Area (m^2)	Pool Volume (m^3) Total	Pool Volume Average	Pool Volume Residual Total	Pool Volume Residual Average	Pool Depth (m) Mean	Pool Depth Max	Pool Depth Tail	Pool Depth Residual	Percent Pool Cover Lsub	Ovhd	Subm	Ucut	% Substrate Composition Fine	Grav	Rubb	Cobb	Bldr	Bdrk	% Grid Fines
Rosgen	B																				
BW6	3	313.5	156.7	52.2	156.2	52.1	0.50	0.95	0.38	0.57	7	20	0	3	13	25	30	23	8	0	30
BW7	2	130.3	19.7	9.9	6.0	6.0	0.15	0.35	0.20	0.20	0	30	5	0	50	23	13	13	3	0	-
BWP	5	162.0	30.3	6.1	14.8	14.8	0.19	0.37	0.20	0.15	4	17	6	7	60	23	7	5	5	0	-
CCP	1	33.6	12.8	12.8	18.5	18.5	0.38	0.80	0.25	0.55	10	10	10	0	5	10	20	15	20	30	8
DP6	10	1187.3	449.1	44.9	482.3	48.2	0.38	0.71	0.27	0.44	8	17	16	1	37	28	14	11	10	0	17
DP7	1	23.1	3.2	3.2	3.7	3.7	0.14	0.30	0.14	0.16	-	-	-	-	30	30	20	15	5	0	-
DPL	2	266.5	65.1	32.5	125.3	62.7	0.24	0.63	0.16	0.47	15	18	10	0	20	40	10	10	0	20	-
EGW	1	13.7	2.3	2.3	-	-	0.17	0.40	-	-	-	-	-	-	30	45	10	5	10	0	-
LS4	4	271.3	85.5	21.4	129.9	32.5	0.31	0.68	0.24	0.44	11	8	4	18	12	19	35	23	12	0	13
LS6	6	311.7	95.1	15.9	172.8	28.8	0.31	0.64	0.18	0.46	5	18	21	6	13	26	37	16	9	0	14
LS7	16	1422.0	426.9	28.5	725.9	48.4	0.31	0.68	0.21	0.48	3	25	10	9	19	31	25	14	11	0	19
LS8	5	312.8	87.8	17.6	139.6	27.9	0.28	0.70	0.27	0.43	18	18	5	10	12	22	26	20	19	2	12
LSP	2	95.9	21.5	10.7	29.2	29.2	0.22	0.58	0.20	0.45	5	15	15	20	48	20	20	8	5	0	8
MC3	1	104.2	29.2	29.2	41.7	41.7	0.28	0.65	0.25	0.40	10	0	0	0	5	5	10	15	25	40	12
MC4	13	1148.4	482.1	37.1	677.1	52.1	0.42	0.95	0.42	0.54	20	7	3	2	13	19	24	18	22	5	11
MC6	4	280.7	111.3	27.8	163.7	40.9	0.40	0.81	0.24	0.58	6	20	17	3	18	19	31	20	13	0	9
MC7	4	456.3	191.2	47.8	319.6	79.9	0.42	0.90	0.26	0.64	6	10	0	3	16	30	23	18	14	0	13
MC8	9	800.0	197.2	21.9	385.8	42.9	0.25	0.64	0.19	0.45	23	10	9	6	16	25	29	19	12	0	13
MCP	1	34.0	11.2	11.2	13.6	13.6	0.33	0.70	0.30	0.40	0	40	20	0	30	45	15	10	0	0	10
PL3	1	95.9	41.3	41.3	-	-	0.43	1.10	-	-	30	10	0	0	5	15	25	20	25	10	9
PL4	5	426.8	135.5	27.1	155.4	31.1	0.32	0.65	0.29	0.36	18	4	0	8	13	24	28	17	16	2	13
PL6	11	683.0	226.5	20.6	318.5	29.0	0.33	0.72	0.25	0.47	13	20	14	5	16	23	28	19	14	0	11
PL8	1	34.2	11.3	11.3	13.7	13.7	0.33	0.70	0.30	0.40	20	20	10	0	10	15	35	30	10	0	10
PLP	9	472.0	134.0	14.9	136.5	17.1	0.28	0.47	0.13	0.34	16	10	21	1	15	33	29	9	13	0	14
USP	7	347.3	107.6	15.4	165.2	27.5	0.31	0.74	0.27	0.48	10	13	10	8	12	23	28	22	15	0	11
Total	124	9426.7	3134.2	25.3	4394.8	36.0	0.31	0.69	0.25	0.45	12	15	10	5	20	25	25	16	13	2	14

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Aquatic Ecosystem Approach to Monitoring

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Abstract.--An outline of a conceptual framework evaluating the effectiveness of forestry Best Management Practices in meeting water quality goals or standards is provided. In order to evaluate the effectiveness of these practices in meeting water quality goals or standards, an aquatic ecosystem approach to monitoring needs to be implemented. Recent guidance from the Environmental Protection Agency for monitoring the physical, chemical, and biological integrity of water will directly influence monitoring in forest streams, including the establishment of reference streams. A stream/ecosystem classification system is needed to insure proper comparisons of impacted streams with references streams. A weight of the evidence approach is needed to determine if Best Management Practices for forestry have met water quality goals or standards.

INTRODUCTION

Section 101(a) established as the objective of the Clean Water Act the restoration and maintenance of the chemical, physical, and biological integrity of the nations' waters. Section 101(a)(2) includes the interim water quality goal for the protection and propagation of fish, shellfish, and wildlife. Propagation includes the full range of biological conditions necessary to support reproducing populations of all forms of aquatic life and other life that depend on aquatic systems (Environmental Protection Agency 1990). The Environmental Protection Agency's (EPA) interpretation of Section 101 is an ecosystem approach to water quality monitoring, including monitoring habitat condition. Therefore, an aquatic ecosystem approach to monitoring will be used.

The EPA has issued guidance for monitoring the physical, chemical and biological integrity of streams (MacDonald et al. 1991, Plafkin et al. 1989, EPA 1990). States are to adopt narrative biological criteria into state water quality standards during the FY 1991-1993 triennium (EPA 1990). EPA expects numeric biological criteria to be adopted in the following triennium, and is in the process of refining the guidance for biological criteria for streams (EPA 1991). EPA's guidance clearly demonstrates an aqua tic ecosystem approach to standards and monitoring.

When forestry evaluates the effectiveness of its Best Management Practices (BMPs) in meeting water quality goals or standards, forestry will monitor to evaluate the effectiveness of BMPs in meeting the physical, chemical and biological integrity of streams. Water quality standards are oriented toward point sources of pollution and the 7-day low flow period. For point sources, exceeding the limits set by water quality criteria during the 7-day low flow period is a violation. In forest streams, temperature during the low flow period can be critical and forestry will have to meet this State water quality criteria.

Most nonpoint impacts from forestry occur in response to rainfall or snowmelt events and during high stream flows, not during low flow periods. Few of the water quality parameters affected by forest management have criteria established reflecting the random nature of nonpoint sources. The basic standard that forestry will be judged against is the designated beneficial use assigned to streams. The focus of forest management will be protecting the designated beneficial use: namely cold or warm water fisheries, recreation, and municipal water supply. Most often, it will be cold and warm water fish. States are developing biological criteria, including habitat, for protect-

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ing the beneficial use-fish. To evaluate the effectiveness of BMPs in protecting fish, forestry will use an aquatic ecosystem approach to monitoring.

To demonstrate effectiveness in meeting state water quality goals or standards, forestry needs to use monitoring methods employed by the state. Why? The numbers generated by monitoring must be comparable with state values (water quality standards). Using the same monitoring methods and laboratory techniques produces comparable data. Also, if state methods and laboratory techniques are used by the forestry community and results are challenged, the forestry response can be: (1) the state has leadership for water quality management, (2) the state establishes water quality criteria and the methods for evaluating compliance, and (3) results are based upon the state's methods and standards. With states implementing an aquatic ecosystem approach to monitoring, forestry needs to do the same and, hopefully, in full cooperation with states.

BIOLOGICAL INTEGRITY

The expression "biological integrity" is used in the Clean Water Act to define the nation's objective for water quality (EPA 1990). EPA (1990) defines biological integrity as follows: "According to Webster's New World Dictionary, integrity is, 'The quality or state of being complete; unit paired.' Biological integrity has been defined as 'the ability of an aquatic ecosystem to support and maintain a balance, integrated, adaptive community of organisms having a species composition, diversity, and functional organization comparable to that of the natural habitats within a region' (Karr and Dudley 1981). For the purposes of biological criteria, these concepts are combined to develop a functional definition for evaluating biological integrity in water quality programs. Thus, biological integrity is functionally defined as: the condition of the aquatic community inhabiting the unimpaired water bodies of specific habitat as measured by community structure and function."

Ecological integrity (Figure 1) is attainable when chemical, physical, and biological integrity occur simultaneously (EPA 1990). Biological integrity includes habitat.

EPA (1990) recognizes the difficulty in finding unimpaired waters to define biological integrity and establish the reference condition. How ever, the structure and function of aquatic communities of high quality waters can be approximated in several ways. First, characterize aquatic communities in the most protected waters representative of the regions where such sites exist. In regions where few or no unimpaired sites are available, characterize the least-impaired systems. Least-impaired streams may occur in watersheds where water quality management is excellent. Biological criteria will be based upon the characterization of these reference streams. Because least-impaired systems will be used as references, the realities of limitations on biological integrity can be considered and incorporated into goals for those waters and the progressive program to improve water quality.

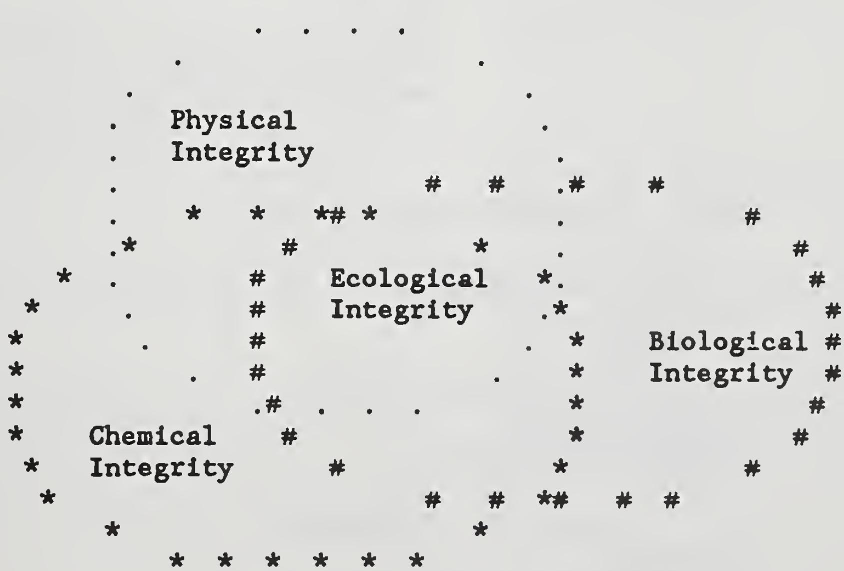

Figure 1. The elements of ecological integrity.

EPA MONITORING GUIDANCE

EPA has recently published guidance for evaluating the physical, chemical, and biological integrity of waters. A wide range of parameters are identified for monitoring, with flexibility to reflect varying biotic communities and regions of the country.

EPA Region 10 (MacDonald et al. 1991) has published "Monitoring Guide lines to Evaluate Effects of Forestry Activities on Streams in the Pacific Northwest and Alaska." This guidance identifies 32 water quality parameters reflecting influences of forest management on ecological integrity (Table 1). The guidance identifies: (1) the designated beneficial uses affected by water quality parameters, (2) a sensitivity of monitoring parameters to management activities, and (3) the relative frequency and cost of data or sample collection by monitoring parameters. The guidance is coupled with an expert system to help in planning a monitoring program based upon the availability of time and money.

These 32 parameters address the chemical, physical and biological integrity of water systems, and they demonstrate an aquatic ecosystem approach to monitoring. The rapid bioassessment protocols (RBP) uses an ecosystem approach to monitoring (Plafkin et al. 1989).

The methods characterize physical conditions operating in the watershed, including: land use, watershed erosion, stream width, stream depth, high water mark, stream velocity, presence of a dam, channelization, canopy cover, sediment characterization, and substrate components.

The RBP includes a habitat assessment procedure for comparing study streams or stream segments with reference streams or stream segments. (The term "study" is used because monitoring will determine if BMPs have or have not met water quality goals or standards.) Nine conditions or parameters are used (Table 2). The reader is referred to Plafkin et. al. (1989) for an explanation of these parameters.

Table 1. Water quality parameters influenced by forestry activities.

Category of water quality parameters					
Water column	Flow	Sediment	Channel characteristics	Riparian	Aquatic organisms
Temperature pH Conductivity DO Intergravel DO Nitrogen Phosphoru Herbicides/ pesticides	Peak Low Water	Suspended Turbidity Bedload yield	Cross-sections Width Width/depth ratio Pool parameters Thalweg profile Habitat units Bed material: size embeddedness surface vs. subsurface	Canopy opening Vegetation	Bacteria Algae Invertebrates Fish

Table 2. Habitat assessment conditions/parameters.

Primary-substrate and Instream Cover
1. Bottom substrate and available cover
2. Embeddedness
3. Flow/velocity

Secondary-channel Morphology

4. Channel alteration
5. Bottom scouring and deposition
6. Pool/riffle, run/bend ratio

Tertiary-riparian and Bank Structure

7. Bank stability
8. Bank vegetation
9. Streamside cover

The habitat assessment includes a procedure for evaluating each condition or parameter. A habitat score is developed for the reference streams and for the study streams. The habitat score for the study stream is com pared with the score for reference streams. The comparison is made by dividing the study stream score by the reference score to convert to a percentage. The study streams are assigned an assessment category (Table 3). The study stream habitat is classified as either (1) comparable to reference, (2) supporting, (3) partially supporting, and (4) non-supporting for the biotic community. The RBP includes Karr and Dudley's (1981) index of biological integrity (IBI) which evaluates the fish community. The IBI uses 12 metrics (Table 4).

Each metric is scored and summed to get an IBI score. Based upon the IBI score, the integrity class of the site is rated as excellent, good, fair, poor, very poor or no fish. The metrics in Table 3 represent midwest conditions and may need adjusting to reflect other regions of the country.

Table 3. Apparent habitat potential of support an acceptable level of biological health.

Assessment category	Percent of comparability
Comparable to reference	≥90
Supporting	75 - 88
Partially supporting	60 - 73
Non-supporting	< 58

Table 4. Metrics used to assess biological integrity of fish communities.

Species Richness and Composition
1. Total number of fish species (native fish species)
2. Number and identity of darter species (benthic species)
3. Number and identity of sunfish species (water-column species)
4. Number and identity of sucker species (long-lived species)
5. Number and identity of intolerant species
6. Percentage of individual as green sunfish (tolerant species)

Trophic Composition
7. Percentage of individuals as omnivores
8. Percentage of individuals as insectivorous cyprinids
9. Percentage of individuals as picivores (top carnivores)

Fish Abundance and Condition
10. Number of individuals in sample
11. Percentage of individuals as hybrids (exotics, or simple lithophils)
12. Percentage of individuals with disease, tumors, fin damage, and skeletal anomalies

The RBP III evaluates the structure and functions of the benthic invertebrate communities and evaluates the health of invertebrate community against the reference condition.

The RBP combines the IBI and/or RBP III with the habitat assessment to compare the study system with the reference systems. The key is the comparison of fish/invertebrate community health of a study stream with a reference stream. Of vital importance for interpreting data is to insure the stream/ecosystem of the reference stream is comparable to the study stream. These are the tools which states are using to evaluate point and non point sources of pollution in meeting water quality goals or standards. Forests will have to use them, too. Many states are in the process of mapping ecoregions, finding and establishing reference streams, characterizing the structure and function of aquatic communities of reference streams and evaluating the habitat of reference streams. In addition, the reference streams will be evaluated for their chemical and physical integrity. Many of the reference streams are being or will be located in forested watersheds. The forestry community needs to assist the state water quality agencies locate "least impaired" references. The states will lean toward large streams and watersheds when establishing reference streams -- larger streams than recommended to monitored for forestry impacts. To monitor the impacts of forestry BMPs for effectiveness in meeting water quality goals or standards, first to fourth-order streams are needed as reference and study streams. The possibility of accurately evaluating the effectiveness of forestry BMPs decreases with increased stream order. It is unlikely that effectiveness can be judged using fifth and higher order streams.

Ecosystem Interactions with Chemical, Physical and Biological Integrity

Within the EPA's broad ecoregions exists a wide variation in forest streams and aquatic ecosystems reflecting many factors affecting the chemical, physical and biological integrity of waters. The above habitat assessment discussions identify some of these influences. Some additional influences include:

1. Stream order
2. Stream size
3. Drainage area
4. Geology adjacent to streams
5. Soils
6. Riparian vegetation
7. Stream gradient
8. Sinuosity through wetlands
9. Aquatic vegetation and cover
10. Vegetation on watershed slopes
11. Amount of canopy over or shading the stream
12. Watershed sensitivity to change
13. Hyporheic zones
14. Wetlands
15. Elevation
16. Climate--rain vs. snowmelt hydrology
17. Streams flowing
18. Beaver dams and ponds
19. Water withdrawal or augmentation
20. Large woody debris
21. Volume and quality of groundwater
22. Substrate type and heterogeneity
23. Substrate stability

An understanding of how these factors influence the chemical, physical and biological integrity of streams can be used to fine tune classification of reference and study streams for evaluating the impacts of BMPs. Fish and benthic invertebrate communities are influenced by stream size, stream order, watershed area, elevation, stream gradient, and substrate type. The organic energy and functional communities are influenced by the type of detritus from riparian vegetation, the amount of solar exposure of the stream, the presence or absence of large woody debris, the type of detritus inputs from ephemeral streams from vegetated slopes, and the heterogeneity of the substrate. The physical and chemical character of water are affect ed by geology, soils, wetlands, and water withdrawal or augmentation. Geology and soil influence the sensitivity of watersheds to change and for landslide risk. Beaver dams and ponds change the hydrology and water quality characteristics of streams.

In order to have valid comparisons between reference and study streams, a stream/ecosystem classification system needs to be employed. Reference streams and study streams must have the same classification to minimize variation and to insure comparable streams and ecosystems are being judged against each other. Streams of same size, stream order, geology, etc., need to be compared.

Stream/Ecosystem Classification in Forested Watersheds

The EPA is using Omernik's (1987) ecoregion procedure for grouping streams. Omernik's system is an ecoregion framework for interpreting spatial patterns in state and national data. His ecoregion classification is based on regional patterns in land-surface form, soils, potential natural vegetation, and land use. He recognizes the need to refine the classification within the broad ecoregions by suggesting the consideration of stream size, hydrologic regime, and riparian vegetation. The states are delineating and mapping Omernik's ecoregions. Omernik's procedure is a gross classification, wherein, a more refined stream/ecosystem classification system is needed to better focus on forest conditions.

The refined forest stream/ecosystem classifications system needs to consider the influences listed above and the habitat needs of biota living in streams. State water quality agencies are defining biological criteria based upon the structure and function of biological communities for streams by ecoregions occurring in their states. The organisms incorporated in the biological criteria will vary across the country and will have varying habitat needs. These habitat requirements need to be incorporated in the classification of streams and ecosystems on forest land.

In monitoring the effectiveness of BMPs in meeting water quality goals, reference and study streams must be as similar as possible. The watershed should have the same geology, soils, vegetation, aspect and elevation. The streams within the watershed should be classified by stream order. Riparian vegetation should be typed and mapped. The stream channels should be classified by morphological characteristics using Rosgen's (1985) procedure which includes the influences of gradient, sinuosity, width/depth ratio, substrate, confinement, entrenchment, and soil/land form features. The streams should be evaluated and classified for stream bank stability, canopy closure over the stream, the presence of large woody debris,

the occurrence of beaver dams, riparian vegetation, the presence of adjacent wet lands and hyporheic zones.

In monitoring, study streams or stream segments will be compared with reference streams or segments. The stream/ecosystem of the stream segment that a management activity occurs on needs classification, for example: near an order two stream, with alder riparian vegetation, the Rosgen's channel type is a B3 (originally), has a riffle/pool sequence, has a watershed area of 1.0 miles above, conifers were harvested, and the stream has beaver dams and large woody debris. The reference stream or segment should have the similar characteristics to facilitate valid comparisons.

Evaluating the Effectiveness of BMPs

Using an aquatic ecosystem approach to monitoring leads to a weight of the evidence approach to evaluating the effectiveness of BMPs in meeting water quality goals. No one factor probably will stand on its own when monitoring the effectiveness of BMPs.

Ohio EPA (1988) experience has shown that reliance on one component of water quality may not reveal impairment. In an intensive survey, 431 sites in Ohio were assessed using instream chemistry and biological surveys. In 36 percent of the cases, chemical evaluation implied no impairment but biological data revealed impairment. In 58 percent of the cases the chemical and biological assessments agreed, with 17 percent indicating no impairment and 41 percent suggesting impairment. In 6 percent of the cases, chemical evaluation indicated impairment while the biological data showed no impairment. The biological surveys were more reliable because the organisms live in the water and integrate all the water quality impacts, but were not fool proof.

In forest streams, the biological assessment may suggest impairment adjacent or below a management area compared to a reference segment. But, is it a management impact or not? For example, if the reference stream has a large amount of large woody debris (LWD) and there is limited LWD in the study stream, the organic energy regime may not be the same. If the study watershed is young conifer planted on abandoned farm land and the reference watershed has old-growth conifer, they are not comparable in natural recruitment of large woody debris and the problem may be stand age, not the management practice.

There is a continuum from the headwaters to the point of study for effectiveness. The stream/ecosystem classification system leads to a better understanding to the continuum, the ecosystem, and how the watershed is functioning. A good understanding of the system leads to good monitoring.

For a hypothetical situation, lets look at a continuum and see how it might be used to evaluate the effectiveness of BMPs. In the reference stream, the index of biological integrity (I), embeddedness (E) and stream temperature (T) are evaluated along the continuum to the headwaters (Figure 2). In Figure 2, the stream flows from right to left. The stream distance, watershed area and stream order are on the horizontal axis. The variation in IBI, embeddeness and temperature is plotted, trends establish ed and data analyzed.

The same parameters are evaluated for the study stream (Figure 2). The study watershed has two management activities, logging with and without BMPs. Trends in IBI, embeddedness, and temperature can be compared between streams and along streams. Above the logging without BMPs, IBI, embeddedness and temperature variation, and trends appear similar suggesting water sheds are comparable.

As the study stream proceeds past the logging with BMPs, embeddedness (e) is unchanged, temperature (t) increases slightly, and IBI (*) reduces slightly. This variation down stream appears to be within the natural variation of the reference stream and it could be judged that BMPs were effective. Also if the state has biological criteria, if IBI decrease is small and within acceptable limits set by the state, the logging BMPs met their biological criteria. Temperature and embeddedness criteria might have been met, too.

As the stream proceeds past the logging without BMPs, IBI decreases significantly. Is this sharp reduction in IBI caused by the poor logging or is it within natural variation? Is there other evidence to link the IBI reduction to the poor logging? Stream temperature increases close to a critical level as the stream passes the poor logging and 75 percent of the riparian canopy was removed by the logging.

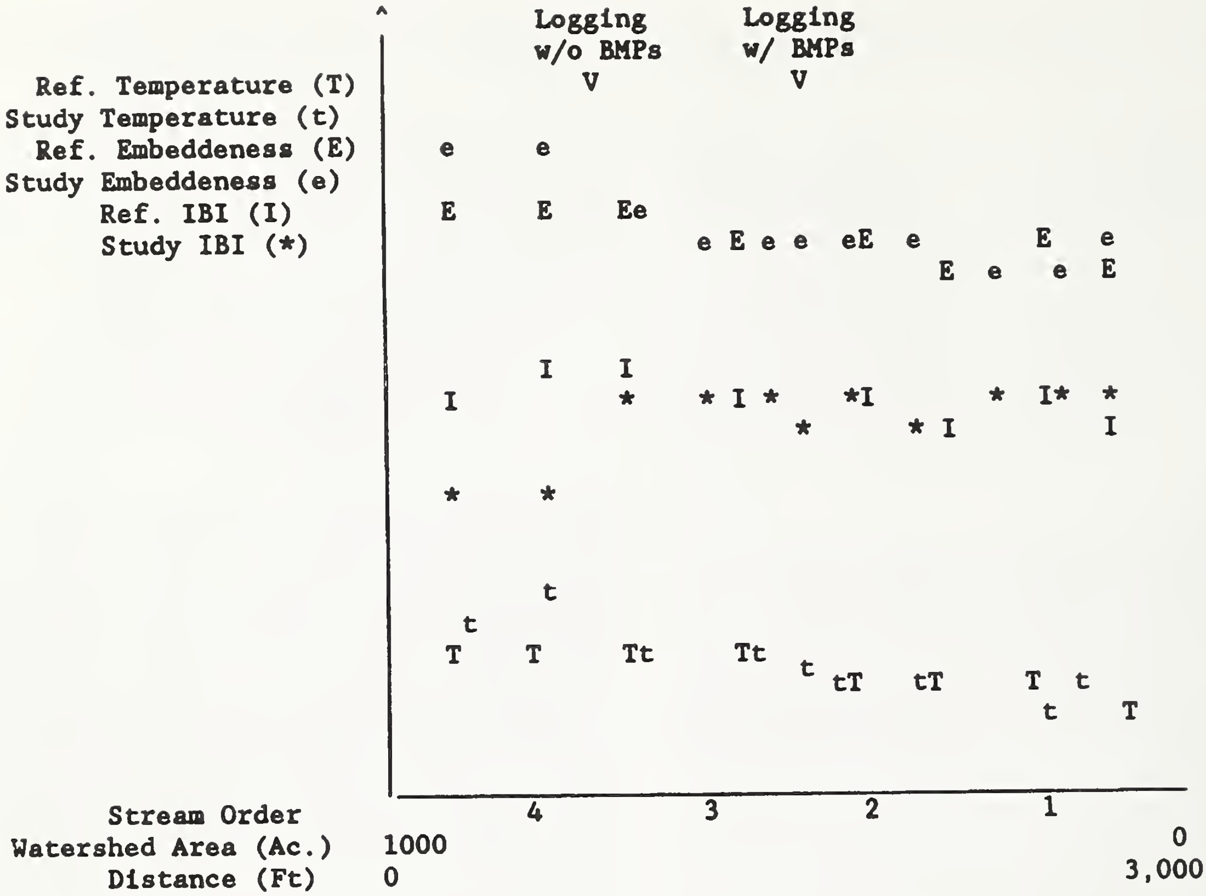

Figure 2. Evaluating study stream and management with reference streams.

Embeddedness in the stream segment adjacent and below the poor logging increases significantly. Soil erosion from the logged area is traced from the slope through the riparian area to the stream. All three responses to poor logging are clear departures from the reference stream and natural variation, and evidence links these impacts to the poor logging. If biological criteria are addressed in state water quality criteria and the IBI reduction exceeds the threshold set in the criteria and the problems cannot be traced to another source, the poor logging does not meet water quality goals or standards. The weight-of-the-evidence approach links the problem to the poor logging.

Another possible approach to evaluating the effectiveness of BMPs is by stream/ecosystem class (Figure 3). For this example lets assume the classification is pine watersheds with hardwood riparian vegetation, the stream order is three, and the Rosgen's stream class is a C4. Several study stream segments and management practices are compared to reference segments. All stream segments are in watersheds with the same stream/ecosystem classification. The management practices are logging with BMPs (Log-w), logging without BMPs (Log-w/o), roads with BMPs (Roads-w), roads without BMPs (Roads-w/o), site preparation using shrearing and windrowing with BMPs (KG- w), and site preparation using chopping and a light burn with BMPs (CB-w). The state has set an IBI criteria in their water quality standards of 30 percent departure from IBI in reference streams. In Figure 3, management practices complying with the criteria can be identified. In this hypothetical example, logging with BMPs, and chopping and burning with BMPs comply with the standard. Roads with BMPs are borderline with com-

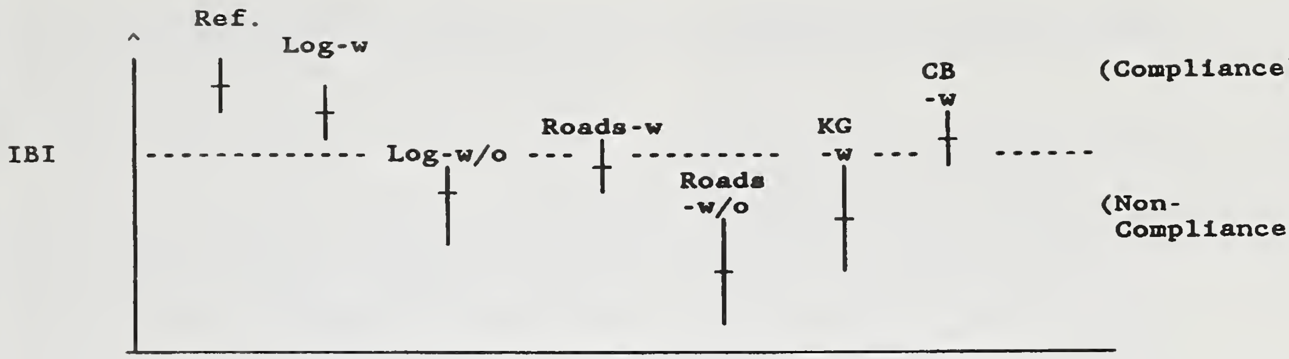

Figure 3. Comparison of management impacts on index of biological integrity.

pliance. Logging without BMPs, roads without BMPs, and shearing and windrowing with BMPs are found to be in noncompliance.

Because of the natural variation in reference and study streams, more than one reference and study stream need to be used in evaluating BMPs. At a minimum, three or four reference and study streams should be monitored and are needed for statistical analyses and inference.

CONCLUSIONS

Water quality management is maturing and incorporating an aquatic ecosystem approach to monitoring and management. It requires an interdisciplinary and interagency effort to implement. The chemical, physical and biological integrity of water is the goal and the basis for water quality standards. The evaluation of forestry BMPs will require the utilization of state methods to insure comparable data and credibility of data interpretation. The forestry community and state water quality agencies need to work closely together in planning, monitoring, and evaluating of the effectiveness of BMPs in meeting water quality goals or standards. The forestry community should participate in the process of selecting reference streams as many of them will be in forested watersheds. We need to insure reference and study streams are comparable, so that forestry BMPs are fairly evaluated.

National and state efforts to classify streams by ecoregions needs to be refined to evaluate the effectiveness of forestry BMPs. The refined stream/ecosystem classification for forest streams needs to tier down from the state's ecoregion efforts and focus on the influences affecting the physical, chemical, and biological integrity in the forest environment. A good understanding of the forest stream/ecosystem will lead to better monitoring, better interpretation of data and better water quality management.

A weight-of-the-evidence approach to evaluating the effectiveness of BMPs should be employed. No one factor should be used in the forest environment to judge whether BMPs meet water quality goals or standards. Many factors other that the management practice under study can be the source of the problem. The stream/ecosystem classification should eliminate some of the noise in the system and improve the evaluation of BMPs. Because of natural variation, several reference and study streams need to be evaluated to define the variation and allow statistical methods and inference to be used. When the weight of the evidence reveals that several parameters or conditions are or are not significantly altered, the judgment of effectiveness of BMPs in meeting water quality goals or standards can be made.

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Statistical Basis Of Water Quality Monitoring

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Abstract.--Typically, the first connection between statistics and water quality monitoring programs is when the data are analyzed. While analysis is a major function of statistical methods, monitoring programs sometimes suffer from not applying statistical principles during the planning and operational phases. Because properties of estimates and formal testing procedures depend on how data are collected, it is best to consider these properties when the collecting process can be revised to help produce the desired results. Nonstatistical methods are sometimes used to collect and analyze data which generally produce estimates with unknown properties. Reasons for using statistical methods and for integrating their requirements into the early planning and operational phases are discussed and explained. The increasing scrutiny to which Forest Service monitoring will be subjected encourages using the best data collection and analysis methods. The complicated and varied nature of many water quality monitoring plans and their importance to management suggests that the Forest Service should provide formal statistical assistance in their development.

INTRODUCTION

Problem

Legislative direction and interest by Forest Service management and the public has increased effort in monitoring water quality in national forests. Although statistical techniques are often used to analyze data once collected, they are more profitably applied throughout a study. Several basic statistical principles are commonly misunderstood or ignored when water quality monitoring programs are planned and operated. Some of these factors are reviewed and their importance explained to encourage their use when establishing and operating monitoring studies.

Statistics is sometimes viewed as a hindrance in setting up and operating a study. Indeed, extra effort is sometimes needed to include statistical factors in study planning and rigorously follow statistical dictates during measurement. However, attention to statistical details is generally beneficial. The purpose of collecting data is to obtain information about quantities of interest. If results do not contain the information sought, the effort and expense are at least partly wasted. Using appropriate statistical practices throughout a study helps ensure that the results perform as expected; with a level of performance that can often be planned into a study. Statistical planning also reduces effort needed during analysis and helps avoid surprises about data limitations.

Themes

Two major themes underly the comments made here. The first theme is that the results of any study or monitoring program <u>always</u> depend on the way in which the data are collected. The methods used to select data from the population for inclusion in the sample, whether due to a formal probabilistic sampling plan or to some unspecified informal set of procedures, control the characteristics of the possible

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outcomes of repeated application of the plan. In particular, the bias and variance of the distribution of results (estimates of total loads, for example) are influenced by the sampling method used.

The second theme is that the results of any study should have known and desirable properties. For example, a hydrologist may want to know that a result is unbiased and that it has a 90 percent probability of being within 20 percent of the true value. The properties of the distributions of outcomes of statistical sampling plans are understood and their associated estimators can be structured to perform in ways required in particular monitoring contexts. Water quality monitoring studies should use statistical plans to ensure that the outcomes perform in known ways and to ensure that valid comparisons can be made.

Control can be exerted over the validity and sensitivity of estimates and comparisons made from data collected during monitoring. Familiarity with a variety of sampling plans and methods for comparing treatments enables a hydrologist to select procedures that make the most efficient use of effort and money for a given problem.

QUESTIONS

Water monitoring programs are carried out to answer one or more questions about the quality of a given river or rivers. What is the sediment load in a given stream? Has the water quality in a river changed because of particular management actions? Questions such as these are central to planning water quality monitoring studies.

However, the questions must be specific before they can be used as guidance in selecting appropriate statistical procedures. General goals should be refined to be sufficiently specific to enable selection of a statistical model as well as to satisfy a management need. The above question about sediment load might be refined to relating the storm loads of the managed river to those from corresponding storms in a nearby river used as a control. Or, instantaneous loads could be compared between stations above and below a disturbed area. The statistical tests and the associated sampling requirements are very different depending on which question was selected.

Although much writing is already required of contemporary forest hydrologists there are good reasons to insist that a written plan be prepared for every monitoring program. In particular, the questions the program is intended to answer should receive careful attention in these plans. Documenting the basic goals and reviewing the refining of these goals to specific model-related questions has at least three major benefits. One benefit is that writing down the questions forces the planner to go through a more thorough logical process to identify and understand all aspects of the tentative monitoring program so there are fewer surprises at the end of a study.

A second benefit of preparing a monitoring plan, made more feasible by the first, is that it facilitates peer review of the plan by other hydrologists and statisticians. Such reviews help ensure that a proposed monitoring study produces valid results useful to management.

Finally, written plans lend an element of permanence to a project. It is helpful to have a document where the study planning can be reviewed by those responsible for operating the project. Most water quality monitoring programs continue over extended periods, often exceeding the tenure of the study planner. Especially in such cases, it is essential to have a written plan to enable management and hydrologists who follow to understand the original program and to complete it successfully.

STATISTICAL MODELS

Statistical models define the structure and relationships among the statistical elements in a particular problem. Statistical models are intended to be useful in a wide class of real-world situations. Often it is necessary to make assumptions concerning model structure so that the mathematical development can be completed. These assumptions may require such things as all units in the sample coming from the same distribution or that the measurements be independent.

Generally, a modicum of effort can meet the requirements of a given model which assures having all the benefits of a truly statistical sample and estimator. Common (but not universal) requirements for many statistical models are sampling from the same population, independence among sample units (assured by random sampling), and normality. The model defines how the data should be collected which further supports the need for choosing the model before selecting the data. Within the set of

available models one should be chosen that best meets the conditions and needs of the monitoring plan being undertaken.

Populations

The science of statistics enables one to make inferences about populations. Statistical populations consist of sets of values ("units") that characterize some property of interest in an investigation. Populations are often thought of as being comprised of physical objects, but statistical populations consist of measurements of some characteristic (perhaps of a set of objects). Populations can virtually never be measured in their entirety, so they must be sampled. Statistics consists largely of making inferences from samples back to populations.

Before sampling can be done it is necessary to know exactly what values are in and which are not in the population. While this may seem obvious, data are commonly collected in studies where the population has not been defined. For example, sediment rating curve data may be collected from one population (i.e., one time period) and then applied to a different one. Before collecting any data, careful attention should be given to a precise description of the population. Doing this not only helps from a sampling standpoint, but also assists in deciding whether or not information about a population being considered will be useful to management.

There are two dichotomies pertaining to populations that can help in the process of defining a population. One is that populations can be finite or infinite. Populations of the incomes of persons in a given city, for example, would form a finite population. The possible set of measurements that could be made of the area of a watershed is an example of an (at least conceptually) infinite population.

Another dichotomy is that between "target" and "sampled" populations. A study is carried out for the purpose of determining something about a "target" population. However, target populations are often not accessible so samples must be taken from another population which is accessible, the "sampled" population. This may be a part of the target population or may consist of units related to it in some known and logical way. The sample is taken from and inferences are made back to the sampled population. At some point an investigator is likely to behave as though the sample infers back to the target population. This tendency should be conditioned on an honest assessment of how well the particular target and sampled populations coincide for the characteristic being investigated.

A graph of suspended sediment load over time for an artificial storm illustrates these ideas (Figure 1). Conceptually, at any time during the storm the instantaneous sediment load is given by the smooth graph so the target population is infinite. Practical realities of measurement make it easier to consider the population composed of loads delivered in "short" time periods defined by measurements of discharge and concentration made at their midpoints and applied to the entire period. This finite sampled population, formed from an infinite target population, is then sampled. Period length is chosen short enough to ensure that the two populations are sufficiently alike in their pertinent characteristics.

Sampling

Sampling is deciding which of the population units will actually be measured (i.e., be included in the sample) and therefore used in the estimates. It should be clear that the properties of the estimates (and, therefore, the utility of the conclusions to be made) must depend on how this selection is carried out.

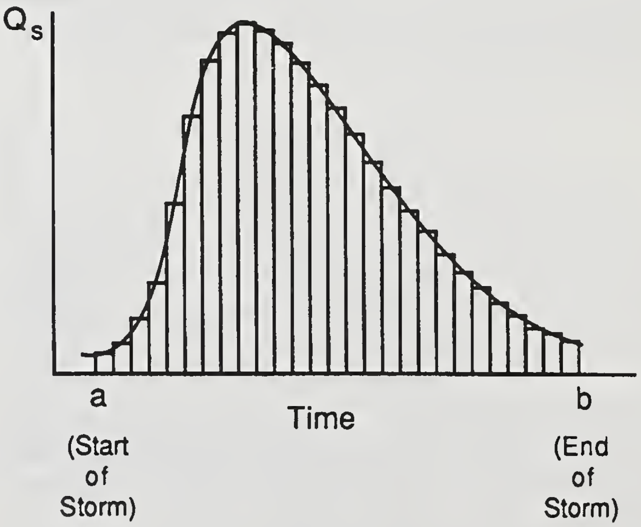

Figure 1. Illustration of typical finite sampled population of sediment loads formed from infinite target population.

There are many ways to select samples. Specialists often believe that they can select units that "typify" a population in some (usually undefined) sense. "Haphazard" sampling attempts to mimic random sampling by "not paying attention" to how samples are collected. Experience shows that these and other "nonstatistical" schemes do not generally have the properties that random samples do. Therefore, using formulas based on random sampling with samples collected by nonstatistical schemes gives misleading results. It may be possible to develop estimators for certain nonstatistical techniques, but only after much effort and, then, they would apply only in specific circumstances. This is because the general variation of nonstatistical selection procedures cannot be described by any known (or sometimes "knowable") mathematical pattern.

However, the mathematical patterns of the class of sampling methods based on the random selection of population units using random numbers are understood. These statistical, probability, or random samples shift the selection process from the investigator to sets of random numbers that possess known properties. Provided the sampler correctly applies one of many random methods and uses the associated estimators, the results will have the properties claimed regardless of the population to which they are applied.

A significant property of samples is that each one can be different. Because the set of population units comprising a sample varies over different samplings the results computed from a set of samples (i.e., the estimates) also vary. For random samples the pattern of variation is known and can be used in statements made about the estimates.

Measurement

Measurement is the process of quantifying population units selected for a sample. Measurements often involve the use of mechanical and electrical devices, techniques that specify their proper application, and assumptions about how they are best applied to quantify the phenomena of interest. Hydrological measurements are often indirect as is exemplified by the many submeasurements of distance, depth, and current velocity needed to calculate a single river discharge.

For all of these reasons measurements also vary. Even for the same sample, variation in measurements could result in different sets of data and, therefore, different estimates.

Much can and should be done to reduce measurement error. As improved instruments and devices become available they can be used to reduce measurement error. Developing good measurement procedures and ensuring that they are applied consistently is another way to reduce variation due to quantifying the population units selected for a sample.

Variation

Variation is the essence of the statistical problem. Without variation there would be no need to make statistical (i.e., probability) statements. A few data could be gathered (the number depending on the problem) and some mathematical equations solved to obtain exact values of parameters. There are a few situations where variation can be ignored, but these are occasional curiosities rather than the norm. For real-world populations in general and natural resource populations in particular, variation should always be considered.

Variation is present regardless of the way in which data are collected; so ignoring statistical methods does not remove the problem. Nonstatistical methods are characterized by our not generally being able to determine the magnitude of their variation. With statistical methods, although variation may sometimes be higher than with certain nonstatistical methods, we understand what steps to take to reduce variance and how to estimate its magnitude from sampled data.

Variation cannot be eliminated in any general monitoring situation, but it can often be reduced and its residual magnitude estimated. The best strategy is to choose a sampling method that gives acceptable sampling variation, set up procedures and use instruments to minimize measurement error, and estimate the variation using valid statistical estimators.

We reiterate that the results of a study depend on how data are collected. In particular, formulas for calculating variance make assumptions about how the data are sampled. It is therefore necessary for proper estimation of variance that the formula for its calcula-

tion be correctly matched with the method used to sample the data. Such matching can only be done with statistical sampling plans.

ESTIMATORS

"Estimators" are algorithms or mathematical expressions that produce "estimates" from samples. That is, estimators are the procedures used to calculate quantities of interest (e.g., means, variances, regression slopes, etc.) from collected data. Because samples vary, the estimates made from them also vary. This variation extends over all of the possible samples of the same size that could be collected for a given set of conditions; the distribution of possible outcomes.

Of course, we usually have a single sample and see the results of only one of the many possible outcomes. The characteristics of estimators are assessed using properties of the distributions of all possible outcomes. The hydrologist should appreciate that the result of a particular sample is just one of a large number of possible outcomes. Willingness to believe a particular result should be tempered by a consideration of the magnitude of the variance.

Properties

Statisticians and others (including hydrologists) have spent considerable effort designing estimators that have desirable properties. Several properties are commonly used to assess and compare the distributions of estimators; two of the more important ones being bias and variance. Bias is the difference between the expected value of the distribution of estimates (loosely, its mean value) of a particular estimator and the true value being estimated. Bias gives a measure of the average distance of an estimate from the true value of the parameter of interest. For many statistical models the average difference between an estimator and the parameter is zero, in which case the corresponding estimator is said to be "unbiased." Sometimes it is reasonable to accept a small amount of bias if by so doing the variance can be sharply reduced.

Variance is a measure of the dispersion of the estimates around their mean. Clearly estimators having low variance are preferred, because there is a better chance that a given estimate will be close to its mean. The best of all possible worlds is to have an estimator that is both unbiased (or has little bias) and has low variance. Then the probability is good that an estimate is close to the value of the parameter being estimated. To illustrate these ideas we apply several estimators to a set of real data.

Suspended Sediment Load Example

Water discharge and suspended sediment concentrations collected from the North Fork of the Mad River at 10-minute intervals for a seven-day period in 1983 enabled calculation of 1008 sediment loads (Figure 2). We consider this to be the entire population and sample it with five different schemes. Histograms of 500 simulated samples of this population are used to visually compare the estimators. All samples have 21 measurements, or an average of 3 per day. Total loads for all schemes were estimated by multiplying the sample average by 1008.

The first estimator models a nonrandom scheme with measurements over an approximately three-hour period starting at 1100 on each of the seven days. A varying number of measurements are taken each day totaling 21 for the week. Although random numbers were used to vary the number of daily measurements and their timing, this is not a valid random sampling scheme since many population units have zero probability of being included in the sample. The narrow histogram for this sampling scheme implies small sample variance, but it is located some distance to the right of the true load (Figure 3). Therefore, while the average estimate is fairly close to the mean of the estimator, the scheme is biased about 39 percent above the true load.

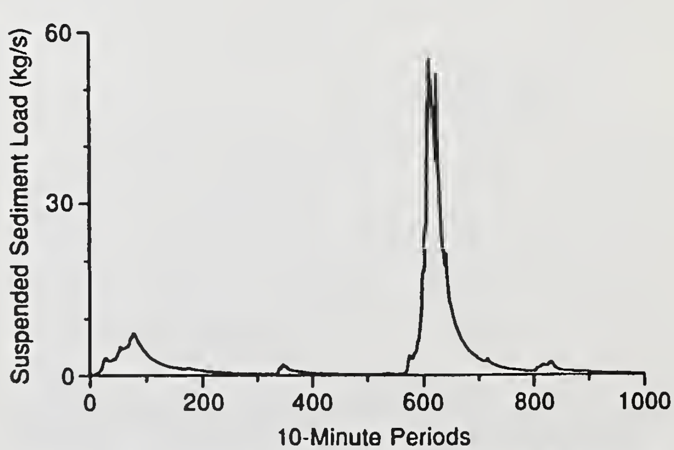

Figure 2. Graph of 1008 10-minute suspended sediment loads (1 week) measured at the North Fork of the Mad River in northern California in 1983.

The second scheme is identical to the first except we attempt to model a more energetic hydrologist who arrives at the station at 0600 each morning. Clearly this tactic does not serve well since the histogram for this scheme is about 275 percent above the true load. Also, the sample variance is dramatically increased as evidenced by its lower and wider histogram.

The important lesson is that there is no general method of applying a nonstatistical sampling plan to obtain known behavior of the estimates without knowing the entire population. Because the scheme does not include population units in the sample with known probabilities it is "population specific" and will perform in different and unpredictable ways for each population to which it is applied.

The last three schemes are random, the first of these being simple random sampling wherein each of the population units has an equal probability of being selected. This is a valid statistical scheme, but is not a good one for suspended sediment because sediment populations are episodic and are better sampled by methods that emphasize measuring during periods of high flow. Still, simple random sampling is a benchmark statistical method that is useful for comparison.

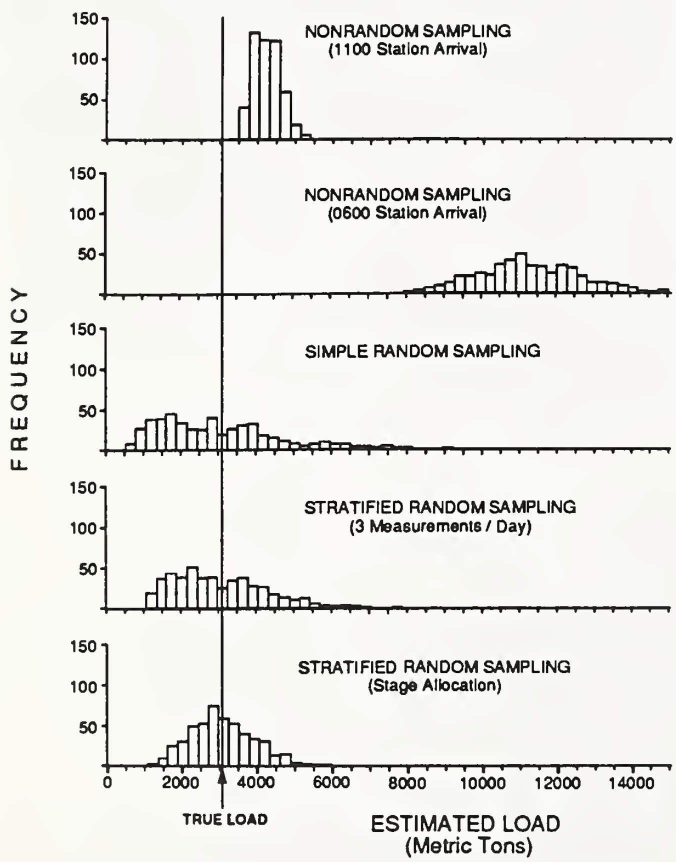

Figure 3. Histograms of sampling distributions (based on 1000 simulated samples) for 5 sampling schemes for the Mad River data. The known true load for the period is also shown.

An obvious difference for the third scheme is that its histogram is centered over the true load. Simple random sampling is known to be unbiased and the histogram being centered over the true load merely illustrates the fact. This property holds for <u>any</u> population so population information is not needed to be certain that this scheme is unbiased. The variance of simple random sampling can be fairly high, however, and the distribution of estimates is somewhat positively skewed which encourages investigation for another random scheme with lower variance.

A widely used sampling method is stratified random sampling. A population is divided into strata and each stratum is randomly sampled. Independence in sampling allows adding stratum estimates of corresponding properties to obtain estimates of population parameters. These estimates nearly always have lower variance than simple random samples of the entire population.

The fourth scheme uses daily strata and three measurements are randomly allocated to each day. Stratified sampling is also unbiased and the expected lower variance of stratified random sampling is evidenced by the histogram still being centered over the true load, but the pattern being less widely dispersed than for simple random sampling.

The performance of stratified random sampling can be improved by taking advantage of knowledge of the population and increasing measurements during periods that contribute more heavily to the total sediment load. Such periods occur during higher discharges, and one way to emphasize high-discharge sampling is to use the beginning stage for each day to proportion the 21 measurements throughout the week. Suppose s_i is the first stage for the ith day and S is the sum of the beginning stages across all seven days. Then the sample size for day i is the integer closest to $21*(s_i/S)$. This method was used for the fifth scheme. Again the estimator is unbiased, but the variance is reduced as indicated by the histogram being more tightly (and more symmetrically) distributed around its mean.

Other data from these simulations help to compare the sampling schemes (Table 1). The first column identifies the sampling method and the second column gives mean loads estimated by each scheme. Comparing these means to the known true load of 3058 metric tons estimates the bias for each method. The nonrandom schemes are 39 and 275 percent above the true load while all of the random methods are well within 1 percent.

Another important factor is variance estimation. Variance exists for all sampling and estimating procedures; it can be reliably estimated only for statistical schemes. The means of the sample variances computed for each of the 500 samples are shown in column three. For the two nonrandom schemes there is no known general formula to calculate variance (and such a formula would be population specific) so the "usual" (simple random) variance formula was used to simulate its "naive" use. The appropriate formulas were used for the three random schemes.

Variance of the estimators of total load can also be calculated by applying the usual formula directly to the estimated loads for the 500 simulated samples. This method works for all schemes (nonstatistical as well as statistical) and will be close to the average of the individual variance estimates if the scheme performs well. These "true" variance estimates are given in column four.

Table 1. Statistics on Monte Carlo sampling with five schemes on 1008 10-minute suspended sediment loads collected in a 7-day period in the North Fork of the Mad River in northern California in 1983. The true period load is 3058 metric tons. NR indicates nonrandom sampling, SRS is simple random sampling, and STR is stratified random sampling.

Scheme	Mean Load (MT)	Variance (1000's) Mean Sample Variance	"True" Variance	Mean Squared Error (1000's)
NR (1100)	4262	905	125	1575
NR (0600)	11465	14450	1882	72560
SRS	3043	2674	2868	2868
STR (3/day)	3069	1670	1555	1555
STR (Stage alloc.)	3077	703	693	693

Columns three and four for the two nonrandom schemes are very different, showing that a variance estimate derived from these schemes using the usual variance formula is likely to be misleading. In these cases the variance estimates tend to be much higher than the true variance. For the random schemes the values in columns three and four are similar, illustrating the property that these schemes are unbiased for estimating variance. Bias and variance can be compared for the nonrandom schemes in this example only because the population is known; it could not be done in a real-world situation with only one sample in hand. However, the random schemes are known to give unbiased estimates of variance which are available from every random sample without having any knowledge of the population.

Column five contains a quantity that summarizes the effects of bias and variance and allows overall comparison of the estimators. The "mean squared error" (MSE) is the sum of the variance of an estimator and the square of its bias. The bias for these five schemes was estimated by the difference between the known sediment load of 3058 metric tons and the mean load estimate in column two. The variance was estimated by the values in column four. The first nonrandom scheme has fairly low MSE, but the MSE for the second scheme is high. These values are circumstantial; there is no way to predict how changes to this scheme would affect the estimators. The MSEs for the random schemes are generally low and are reduced by using more sophisticated methods. The MSE values for these three schemes is the same as their variance because their bias is essentially zero.

COMPARISONS

Use of Statistical Significance

A common use of statistical methods is to decide whether or not certain propositions are true. Questions are generally cast in terms of the magnitudes of population parameters such as means. For example, a hydrologist might want to know if a particular logging operation affects the mean sediment concentration of a stream draining a logged area. A "null" hypothesis can be formed by stating that the mean is equal to or less than some acceptable value and sample data used to decide whether to accept or reject that statement. If a test supports rejection of the null hypothesis it is said to be "statistically significant."

"Tests of hypotheses" are useful, but test performance can depend on unrecognized factors even for proper statistical samples.

To protect against erroneously rejecting a null hypothesis when, in fact, it is true, a "significance level" is set. A common level is 0.05 (although other values may be more appropriate for certain problems) which protects the test against mistakenly deciding against the null hypothesis (if it is true) more often than once out of twenty tests on average. This is correct procedure as far as it goes, but another equally important side of the test is seldom considered. If the null hypothesis is false, the probability of the test detecting that fact should also be known. In the usual case there are numerous alternative hypotheses, each with a unique probability of rejection. Some of the alternatives are more important than others (in a subject matter sense) and the test should have a sufficiently high probability of detecting those alternatives. Also, the test should have relatively low probability of rejecting hypotheses that are of little concern in the context of the problem. We therefore need to consider the concept of "hydrological significance" as well as statistical significance.

Example

To illustrate these ideas consider the performance of three tests applied to an artificial population of lake saline concentrations. The tests differ only in their sample size. Suppose that the former mean lake saline concentration is known to have been an acceptable 1000 mg/l, that the standard deviation is 400, and that the concentrations can be modeled by a normal distribution (we ignore the remote possibility of negative values). Land management activities are suspected of raising the concentration and we want to ensure that the concentration is not above 1200 mg/l.

We want a test to reject the null hypothesis that their true mean is 1000 mg/l with probability 0.05, but to reject with probability 0.95 when the true mean is 1200 mg/l. That is, the test should allow a one in twenty chance of rejecting a true null hypothesis and another one in twenty chance of not rejecting the alternative hypothesis when the true mean is 1200 mg/l. Details which we omit show that these conditions are met by collecting 43 random observations. For comparison we also consider tests using 22 and 86 observations.

Setting probabilities of rejection for two alternatives enables calculation of sample size which, in turn, sets the probabilities for all other alternatives. To investigate this effect consider the histograms of 1000 samples for each of the three tests under the condition that the true mean is 1125 mg/l (Figure 4). The true mean for the alternative being considered is indicated by the vertical bar extending through all graphs. The shorter vertical bars in each histogram indicate the critical point for each test; if the sample mean is greater than this value the null hypothesis is rejected.

Each test behaves quite differently. If the true mean is 1125 mg/l and 22 observations had been collected the rejection rate would be about 42 percent, for 43 measurements about 65 percent, and for 86 observations about 89 percent. It may at first seem that the test that rejects with the highest probability would be preferred. However, this should depend on the importance or "hydrological significance" of detecting a concentration of 1125 mg/l. The 43-observation test was designed to meet two criteria: a significance probability of 0.05 and a 0.95 probability of detecting a mean of 1200 mg/l. The 43-observation test has lower than 95 percent probability of detecting an increase of 125 mg/l, but this increase is smaller and not as critical. Because setting probabilities for rejecting two alternatives establishes the probabilities of rejecting all other alternatives, it is useful to have a more complete picture of test performance.

A more comprehensive comparison of these tests is a plot of their "power curves" (Figure 5). Power is the probability of rejecting a test and power curves show probabilities of rejection for alternative hypotheses of a parameter. The power at the null hypothesis is 0.05 for all three tests which is the significance probability. The curves rise for larger true mean concentrations which is expected; the greater the departure of the true mean from the null hypothesis the easier that fact should be to detect. And the curves for the tests with larger sample sizes rise more steeply. This is also expected; having more information should allow more sensitive detection of differences.

When the true mean is 1200 mg/l the test with 43 observations has power of 0.95 which meets the intended design. If only 22 observations had been obtained the chance of detecting an increase of 200 mg/l is about 0.75 so that the test would be wrong about one time in four on average. For a sample size of 86 observations the rejection probability is 0.998 so the test would almost always detect this level of

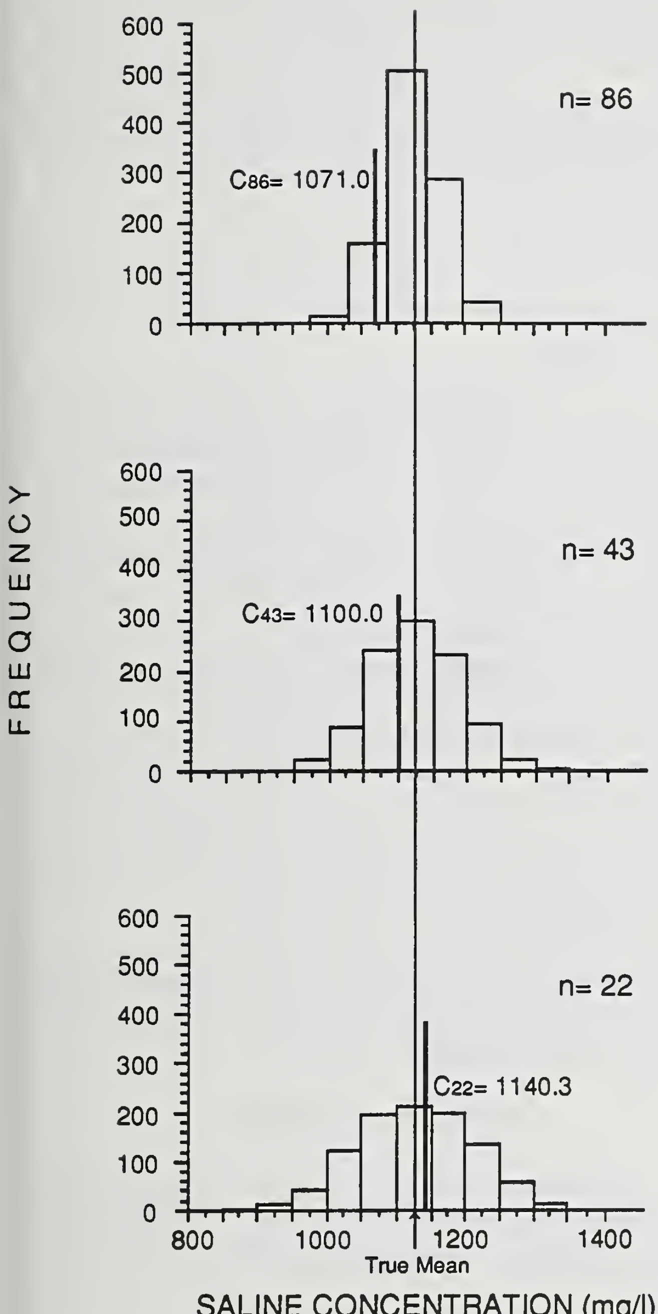

Figure 4. Histograms of distributions of sample means (based on 1000 simulated samples) for three tests of the null hypothesis that lake saline concentration is equal to or greater than 1000 mg/l given a true mean of 1125 mg/l. The tests had sample sizes of 22, 43, and 86 observations and critical levels, (C_n), which, if exceeded by the sample mean, signal rejection of the test. The data were generated artificially assuming normality and a standard deviation of 400 mg/l.

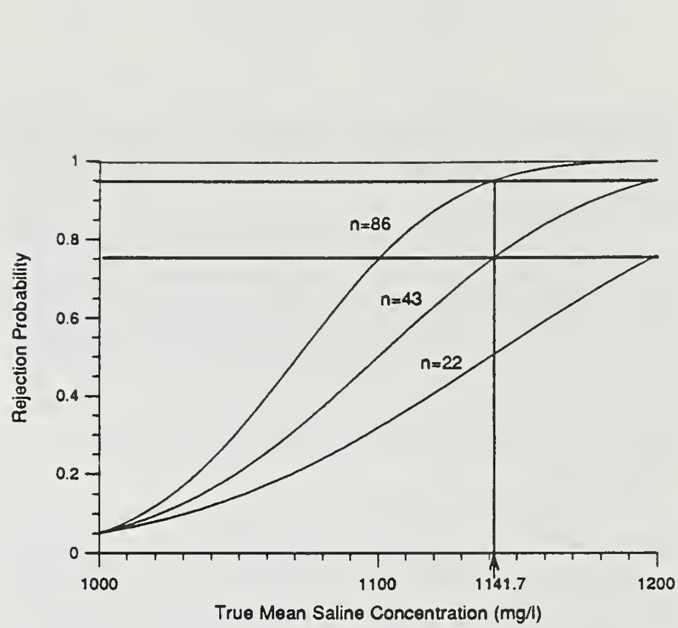

Figure 5. Power curves for the three tests of the artificial lake saline concentration data.

difference. However, the test would detect a true mean concentration of 1140 with a probability of 0.95, so the test would have a high probability of detecting a smaller difference than was deemed to be hydrologically significant.

Therefore, the performance of a test is heavily dependent on sample size and bigger samples are not always better in the sense that they may not accomplish the aims of a test. Ignoring this aspect of study planning effectively turns test performance over to the fortuitous choice of sample size. Tests should not detect hydrologically unimportant differences with high probabilities any more than they should have too low a probability of detecting important differences. In real-world problems calculating power is often difficult mainly due to having insufficient information on variances. However, rough estimates are usually possible and can help avoid either of these shortcomings.

SUMMARY

Using statistics only after collecting data restricts the usefulness of the methods because the results of any sampling and estimating procedure depend on how data are collected. Because we also want methods that perform in desirable ways it is essential to do statistical planning before data collection begins. Not planning can reduce the benefit/cost ratio below an acceptable level for a given situation. The likelihood

that our work will be more closely scrutinized in the future lends additional urgency to this recommendation.

General questions to be answered by data should be made specific enough to enable selection of appropriate statistical analyses. The question-refining process should be written into the monitoring plan to encourage detailed consideration of the problem, facilitate technical and statistical review, and lend some permanence to the original thinking that went into the plan.

The population of interest should be conceptualized and the population available for sampling well-defined so its units can be selected for the sample. Some idea of how these populations relate should be determined to assess the usefulness of the results.

The results of a study depend on how the samples are obtained regardless of whether the sampling is statistical or not. The only generally applicable set of sampling techniques having known properties are statistical methods. Many statistical models exist so that appropriate techniques are available for a wide range of purposes.

Measurements should be made with good instrumentation and according to well thought out and administered methodologies. Such techniques help reduce measurement error to a minimum and avoid influence of measurement methodology on the study results.

Errors in sampling and measurement always result in variation in the outcome of study results. The major difference between nonstatistical and statistical methods is that valid estimates of variance can be obtained in the statistical case. Study planning should always attempt to use a sampling plan that reduces variance as much as possible, maintains careful quality control on all measurements, and estimates the remaining variance.

The performance of estimators is assessed by their distributions. Two important properties are unbiasedness and valid estimates of variance. Most commonly used statistical estimators are unbiased, or nearly so, and virtually all provide for variance estimation. A major benefit of these estimators is that they apply to all populations so their efficacy in particular cases is not in question. Nonstatistical methods may work well under specific situations, but a great deal of information is needed to know when this is true, and such verification is not generally applicable for other situations.

Formal statistical comparisons should be designed to perform properly in the context of a specific problem. Relying on statistical significance alone can result in detecting differences that have little hydrological significance. Careful thought should be given to exactly what level of departure from the null hypothesis is important and with what probability it should be detected. Otherwise the test can be controlled more by the accident of sample size than by the desired performance of the test. Attention should be given to the power of a test to ensure that the probabilities of rejection at various critical levels are neither too small nor too large.

Many of these suggestions can be applied directly, but for some studies selection and adaptation of appropriate methods and doing the preliminary calculations can be complex. One reason these problems exist is the lack of readily available statistical expertise for field hydrologists. The research stations can sometimes provide assistance, but if all study planners requested assistance these resources could be overwhelmed. It therefore seems appropriate that the Forest Service consider providing a formal mechanism for assisting field hydrologists in setting up, operating, and analyzing monitoring programs. Such a service would cost extra money during lean times, but could go a long way toward implementing only those studies that have a good chance of providing useful information to management.

For further information on this topic, refer to the following publications: Cormack 1971; Mostellor and Tukey 1977; Ponce 1980a, 1980b; Hooke 1983; Filbert 1987; and MacDonald et al. 1991.

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Ecological Role Of Large Woody Debris In Forest Streams

Andrew Dolloff[1]

Abstract.--This paper summarizes the key role of large woody debris (LWD) in mountain streams and its importance to fish habitat. Management strategies are outlined which can provide sources of LWD and maturation of riparian vegetation.

Many species depend on the natural accumulation of trees, branches, and root wads collectively known as large woody debris (LWD) (Harmon et al. 1985). Until recent times, however, most managers considered LWD not as an asset to be managed but as a liability to be eliminated. Stream clearing policies and programs were followed by most Federal and many state land management agencies. Although careful removal of individual trees and debris accumulations is justifiable for safe, efficient navigation of large rivers or to protect individual stream and river crossings, wholesale removal of LWD has radically changed habitats for a variety of species in rivers and small streams all across North America. This paper summarizes the role of LWD in mountain streams and its importance to fish habitat.

WHAT IS LWD?

To be considered LWD, a piece of wood must be at least 1-m long and 10 cm in diameter. Pieces of wood and debris smaller than this also play significant roles in stream ecology but because small pieces are more readily dislodged and moved downstream by flowing water, they have less influence on stream channel morphology and fish habitat. Depending on the size of stream, LWD can be root wads, branches, snags, or detached tree boles. In general, the larger the piece the more likely it is to contribute to habitat. Entire trees with root wads attached are ideal. Even trees that are not wholly within the active stream channel have important functions: both bankside and suspended debris "bridges" (pieces that span the channel) and "ramps" (broken bridges or pieces too short to span the channel) have the potential to influence stream channel morphology in the future.

Large woody debris naturally enters streams after root systems are undercut by flowing water. Trees with weakened root systems are then easily toppled by windthrow or the extra weight of rain or snow. Rates of LWD input vary depending on factors such as size of stream, age, species and health of trees in the surrounding riparian zone, and historical land use. Insect and disease mortality may accelerate this process, but the greatest inputs of LWD can usually be traced to specific catastrophic events such as landslides, floods, and hurricanes. For example: the LWD loading in Basin and Cove creeks on the east side of the Blue Ridge Parkway more than doubled – from 39 to 88 pieces per kilometer of stream channel – after Hurricane Hugo swept over northwestern North Carolina.

Until recent times, most people associated high loads of LWD with streams in the Pacific Northwest. But streams flowing through Eastern forests also had substantial loads of LWD. Inventories of LWD in Southern Appalachian wilderness areas has revealed that streams flowing through natural (never logged or cleared) forests contain much greater amounts of woody material than streams flowing through second growth (disturbed) forests (Figure 1) (Flebbe and Dolloff In Press).

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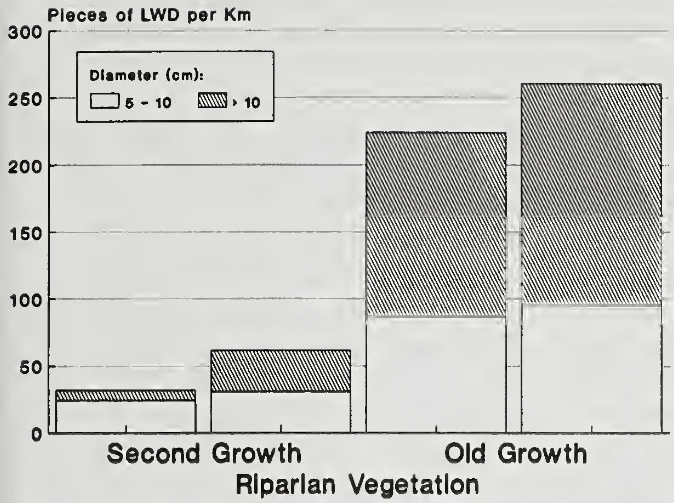

Figure 1. Inventories of LWD in Southern Appalachian wilderness areas.

BENEFITS OF LWD

There are many benefits associated with LWD in streams, ranging from enhanced production of insects and other invertebrates to the formation of critical habitat for fish (Figure 2) (Bisson et al. 1987). Fine particulate organic material stored around LWD accumulations is more readily available for instream processing by macroinvertebrates and microbes (Bilby and Likens 1980). Angermeier and Karr (1984) removed all LWD from one side of a second-order midwestern stream that they had partitioned down the center with 6-mm mesh hardware cloth. The side without debris had smaller amounts of litter, fewer species and lower biomass of benthic macroinvertebrates, and fewer fish species and smaller fish than the side where LWD was left in place.

From a fish's perspective, pool formation is the single most important function of LWD. Streams with few pools have low water storage capacities and consequently tend to have lower fish populations. Many species of fish are attracted to the lower water velocity and greater depth in pools. In mountain streams, trout occupy and defend positions located adjacent to fast flowing water where they watch for insects and other food items that drift by. Pools are especially important to fish during periods of drought, when the only available water may be in pools created by the scouring of sediment from around LWD. After streamflow returns to normal, fish recolonize from these isolated refuges.

Pools form around any material that creates friction and resists displacement by flowing water. While virtually everything in the channel creates friction, including the stream bottom and sides, LWD, boulders, and bedrock protrusions are the most conspicuous pool forming elements. In small to medium sized streams flowing through virgin (uncut) forests, LWD may be responsible for up to 90 percent of all pools. Many mountain streams in the Southern Appalachians flow through old clearcuts or fields and have lost much of their LWD through the natural processes of decay and downstream transport. The percent of pools formed by LWD tends to be much lower (<10%) in streams flowing through these second growth forests because the immature streamside vegetation is not yet able to contribute LWD.

Pools develop around LWD in a variety of ways. Plunge pools result when water flow scours sediment from the downstream side of LWD that spans the channel, dam pools form behind LWD dams, typically at the tops of riffles, and backwater pools are created

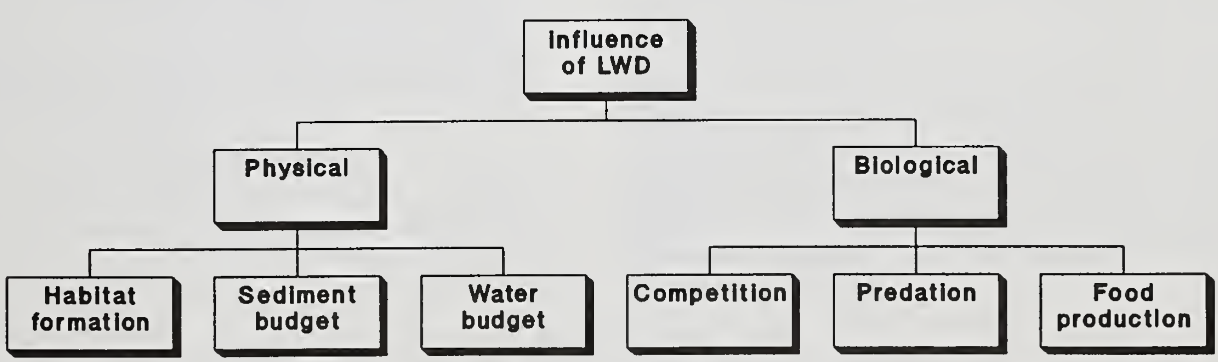

Figure 2. Benefits associated with LWD in streams.

by eddies where the ends of pieces jut into flow. Recent research has demonstrated that the deepest pools form behind pieces that span the entire width of the channel and are oriented perpendicular to flow (Cherry and Beschta 1990).

In addition to the role of LWD in pool formation, complex cover provided by overhanging logs, debris jams, and especially root wads protects fish from predators and excessive competition. This "condominium effect" decreases the number of competitive interactions and permits greater numbers of fish to coexist. Complex cover in deep pools is especially valuable during times of increased stress such as winter. Fish find shelter from flushing streamflows by moving into or behind LWD accumulations. Dolloff (1986) removed LWD (logging residue) from half of the study sections of two first-order Alaska streams and demonstrated that production of juvenile coho salmon and Dolly Varden was greater where debris accumulations were left intact.

IMPACT OF PAST LAND USE

Of the many factors that affect LWD input to streams, the most significant is the legacy of past land use. Engineers have long regarded LWD as a hinderance to navigation on large rivers and an impediment to efficient drainage of small watersheds. Biologists advocated debris removal on the grounds that it might degrade water quality or block fish migration. And nearly everyone agreed that woody debris was unsightly.

We now understand the important role that LWD plays in stream ecosystems. Under natural conditions, large amounts of LWD would be present in most if not all river systems flowing through forested regions, including the southern Appalachians. But centuries of management have changed the composition and appearance of most forested watersheds in the Southeast so that it is difficult for most people to appreciate the importance of LWD. Beginning in the 1700s and accelerating during the late 1800s, logging and land clearing lead to significant declines in LWD and degradation of fish habitat. Transportation systems have traditionally been responsible for most problems (Sedell and Luchessa 1982). Most of our larger streams and rivers were used to float logs to sawmills well into the second half of the 20th century. The term "stream improvement" was used by loggers and rivermen to mean removal of any hindrance to free flow, including not only LWD but also large rocks and boulders.

Splash dams were used both before and in conjunction with railroads; splash damming was common practice in parts of the southern Appalachians. At higher elevations, log flumes and slides were constructed, often in or adjacent to stream channels. Larger streams and rivers were used to float logs to the sawmills well into the second half of the 20th century.

One of the most spectacular examples of stream modification occurred from about 1907 - 1910 on the Russell Fork of the Big Sandy River in southwest Virginia. There, near what is now Breaks Interstate Park, the Yellow Poplar Lumber Company constructed a 360 foot long, 25 foot high splash dam to help transport its supply of yellow poplar timber through the Breaks of Sandy and on to its mill in Coal Grove, Ohio. Forty men labored for two months and used more than 22,000 pounds of dynamite to remove all obstructions in the 15 miles of stream immediately below the dam. Over 50 million board feet of yellow poplar logs (average diameter 25 inches, length 16-38 feet) passed through bays of the dam and down the Russell Fork during the few brief seasons of operation. The effect of the initial stream improvements and subsequent repeated torrents of wood and water on downstream fish habitat and populations was devastating.

Streams and fish habitat continued to be ignored even in later years, when railroads had taken over much of the job of log transportation. This technological advance did little to slow the abuse, as stream gravels were mined to build roads and rails were frequently laid directly over small stream channels. The use of streams and rivers for timber transportation in the southeast persisted well into the 20th century - pulpwood drives on Maine's Kennebec River were phased out only in the 1970s, amidst a storm of controversy.

MANAGEMENT OF LWD

Many people and government agencies still believe that all LWD is bad. Others, however, have embraced recent findings on the importance of LWD and are now adding (replacing) debris. These new policies that recognize the importance of LWD have created some credibility problems for managers and biologists. For years loggers were instructed to keep debris out of streams; now they see fishery and watershed managers not only discouraging stream cleaning but deliberately putting debris back in! Although enthusiasm for adding LWD to streams usually runs high, a word of caution is advised: there is a difference between beneficial LWD and slash -- typical logging residue composed of small trees, tops, and branches (Froelich 1973). Except in the smallest of streams, slash tends to be unstable and contributes little to instream habitat. However, individual trees that accidentally enter a stream should probably be left rather than risk damaging stream banks and accelerating erosion by aggressively yarding them out.

To provide sustainable amounts of LWD for the future, we need to manage not only the stream itself but also the area of direct interaction between land and instream environments -- the riparian zone. Although it is possible to temporarily restore LWD (and a measure of ecological integrity) to individual streams by direct addition of trees, this approach is clearly not feasible on a large scale. Alternatively, given enough time, many riparian areas will regain the characteristics of mature forest and once again provide LWD. Between these extreme strategies lies a range of management strategies; practical, long term solutions that provide "natural" sources of LWD through active management. Future research should address silvicultural relationships in riparian areas, the dynamics of LWD recruitment, and methods to accelerate the maturation of riparian vegetation (Van Sickle and Gregory 1990).

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Placing Large Wood Debris to Restore Salmonid Habitat

Joseph K. Moreau[1]

Abstract.--Fishery managers are placing large wood debris to restore habitats in salmonid streams in the Pacific Northwest. Desirable skills for habitat restoration practitioners are described. A process is presented to plan, implement, and monitor fish habitat restoration projects to maximize the potential for success. Innovative technologies adapted for large wood debris projects are described and sources for tools and materials are presented.

INTRODUCTION

Large wood debris (LWD) has a variety of ecological roles in stream systems. Deposits of LWD are substrates for aquatic invertebrates, provide hiding cover and velocity refuges for fishes, interact with stream flows to form pools and sort sediments, and are important for sediment storage and routing (Sedell et al. 1988, Bisson et al. 1987). Historic practices such as "splash-damming" and "snagging" have led to degraded conditions and simplified habitats in streams (Sedell and Luchessa 1982). In the late 1970s it was still common practice in the Forest Service to remove wood debris jams. In many watersheds, streamside logging of conifers has removed the potential for future large wood debris recruitment for over 100 years.

Fishery managers in the Pacific Northwest and elsewhere have aggressively implemented habitat improvement projects in attempts to restore the productivity of stream habitat for salmonid (particularly anadromous) fishes. Investments in the millions of dollars annually are being made for structural habitat restoration. Placement of LWD to create desired habitat conditions is a common method. Reports on LWD projects indicate varying degrees of success (Everest et al. 1988, House et al. 1989, Doyle 1984, Doyle, in prep).

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In this paper I present skills desirable for habitat restoration practitioners, a process to optimize chances for successful projects, describe some of the technology adapted for LWD projects, and list sources for materials and equipment.

A Slippery Problem

What skills are desirable for a person doing LWD or other fish habitat restoration projects? Watersheds are as unique as fingerprints. Flow regimes, geomorphology, vegetative types, fish species, and habitat condition vary. There are no cookbook solutions to deciding what types of treatments, and their locations, if any, are appropriate. Peter Klingeman (1984) used the term "Hydraulic Intuition" to describe the process used by many practitioners when designing habitat projects. Trial and error experience, discussions with peers, formal education in various physical and biological disciplines, literature searches, and local knowledge of water shed condition, flow regime, and fish life histories all come into play.

Knowledge of aquatic ecology, fishery biology, fluvial geomorphology, hydrology, fluid mechanics, hydraulics, and engineering are typically incorporated in the design, implementation and monitoring of habitat restoration projects. It is not possible to be an expert in each of the subjects, but there are ways to access the skills. One can assemble a team with the appropriate experts or contract for the development of a project. Individuals can develop a general understanding of many of the subjects by reviewing the literature and attending workshops. An indexed bibliography on stream habitat improvement offers numerous citations on techniques (Duff et al. 1986). Two

excellent workshops with manuals are hosted by the University of Washington (College of Forest Resources Continuing Education) and the Oregon Chapter of the American Fisheries Society (Appendix).

A Process to Optimize Success

The Mt. Hood National Forest (NF) in northwest Oregon has developed a process for planning, designing, implementing and monitoring fish habitat restoration projects. The process is a form of adaptive management, a program structure to maximize learning and efficiency. The eight steps are listed and described below.

Step 1. Watershed Inventory

Each project begins with a quantitative watershed inventory using the Hankie and Reeves method (Hankie and Reeves 1988). The method estimates the area for each habitat unit (pool, riffle, glide, side-channel). At each "nth" unit, estimates and physical measurements are both made. Sets of estimated and measured units for each habitat type are used to create a correction factor, allowing an overall estimate of habitat area by habitat type for the watershed. Confidence interval estimates can be constructed. Other attributes are also collected, including pieces of LWD, cover, and substrate. Snorkeling determines which fish species are present, their distribution, and relative abundance.

From these data, a picture is developed of general watershed and habitat condition. Possible limiting factors to fish production may be identified, such as lack of pool habitat due to limited roughness elements (boulders, LWD, or bedrock) or problems with fine sediment. If the latter, erosion control treatments may be more useful than instream habitat work. Once a potential habitat limiting factor has been identified for a particular stream reach, possible treatments can be considered.

Step 2. Project Proposal and Plan

After a limiting condition within a specific stream reach has been identified, a quantifiable objective is developed to address the limiting condition. For example, one may wish to increase pool habitat from 5 to 40 percent of total area within the stream segment. Planning will determine if this is realistic to achieve given the conditions of that watershed and stream reach. Logistical considerations such as access and equipment availability, as well as cost and potential benefits, help determine feasibility. A project proposal and plan are developed, with alternative treatments. Analyses to comply with requirements of the National Environmental Policy Act (NEPA) typically occur at this stage.

Step 3. Pre-project Inventory

Another Hankie-Reeves survey is done within the project reach at a higher level of resolution than the watershed inventory. Subcategories of habitats are noted (such as lateral and backwater pools) and the minimum size for recognition of units is smaller. Fish counts are done by snorkeling with electroshocking verification. The purpose of this inventory is to refine project objectives and develop baseline data for the project reach.

Step 4. Pre-project Peer Review

Project plans are reviewed in the field by a team representing various disciplines. The group typically includes hydrologists and fishery biologists from within the Forest Service, but may include state fisheries personnel, interested citizens, and individuals without a technical background in biology or physical science. The purpose is to validate project designs, timelines, and techniques. Changes may be made based upon on-site discussions.

Step 5. Project Implementation

The project takes place.

Step 6. Post-project Field Review

A group similar in composition to that in Step 4 critiques implementation of the project. Additional work may be recommended. Would a different type of heavy equipment have been more useful? Were the assumptions on equipment costs and time valid? How did the riparian vegetation fare when logs and rocks were yarded? Why did this structure differ in design and location from the original plan? These and similar questions are asked and discussed. Post-project peer reviews may occur immediately after implementation and again after a project area experiences peak flows.

Step 7. Post-project Inventory

An inventory similar to that in Step 3 is done 1 or 2 years after implementation. The objective is to document progress towards meeting project objective(s) by comparing Pre and post-project data. If objectives have not been met, additional work may be recommended.

Step 8. Annual Structure Inventory

Individual structures are reviewed to determine performance in meeting objectives and to check on condition. Maintenance needs are identified.

These steps form feedback loops at various stages of a project with the intent of refining techniques, quality control, and educating persons involved in the program.

INNOVATIVE TECHNOLOGIES

Innovative technologies have been adapted for use in LWD placement projects. They include yarding and fastening methods. Boulders and logs can be placed by-hand in the smallest streams, yarded into position by manual or power winches, or moved by various pieces of heavy equipment including track-mounted or rubber-tired skidders, tractors, or backhoes. An unusual machine used for sites with poor access in the Mt. Hood and other National Forests in Oregon is the Spyder walking backhoe (Dave Hohler, personal communication, Ochoco NF, Prineville, Oregon). The machine has two articulating legs with pads in the front and two articulating legs with wheels in the back. It can climb over 6-feet tall obstacles, and with the aid of a boom-mounted winch, can ascend and descend 100-percent slopes with minimal soil and vegetation disturbance. Helicopter yarding has been used to move boulders and logs (Bob Deibel, personal communication, Clackamas Ranger District, Mt. Hood NF, Estacada, OR; Jack West, Klamath NF, Yreka, CA). Small, winch-powered skylines have been used on the Olympic NF (Curt Ralston, Alsea Ranger District, Siuslaw NF, Alsea, OR).

Cable is often used to fasten logs to boulders. Lightweight, gas-powered, hand-held rock drills (see Appendix for sources for drills, other tools and materials) can bore 3/8-inch holes 10-inches deep into boulders within minutes. Adhesive resin is injected into the cleaned holes and cable is inserted. Cables are wrapped around logs or threaded through drill holes and held with cable fasteners.

A more thorough discussion of methods and materials is found in the manual for the Stream Rehabilitation Training Workshop hosted by the Oregon Chapter, American Fisheries Society (Appendix).

ACKNOWLEDGMENTS

Thanks are due to the biologists and hydrologists on the Mt. Hood NF, particularly Dave Heller (currently Pacific Northwest Region Fish Program Manager) and Dave Hohler (currently Fish and Wildlife Staff Officer, Ochoco NF), for the development of the eight-step process for planning, implementing, and monitoring fish habitat improvement projects. Also, thanks to Scott Bettin with the Bonneville Power Administration in Portland, Oregon, for his time and energy in developing an equipment checklist and source list for materials and tools for habitat projects.

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APPENDIX

Trainings in Stream Rehabilitation

I am aware of two highly-regarded training sessions on the subject in the northwest. Each training session provides a detailed manual. Subject matter is comprehensive, including planning and design considerations, methods and materials, monitoring, hydraulic theory, and fisheries biology. Contact persons/ organizations are listed.

1. Designing and Implementing Habitat Modifications for Salmon and Trout: A Short Course. March 24-26, 1992, Pack Forest Conference Center, Eatonville, WA. College of Forest Resources Continuing Education, University of Washington.

   Dr. Jack Orsborn (206-379-9114)
   50 Nantucket Place, Port Townsend, WA 98368

2. A Training in Stream Rehabilitation, Emphasizing Project Design, Construction, and Evaluation. Oregon Chapter American Fisheries Society (typically held annually in February at different locations in Oregon).

   Oregon Chapter American Fisheries Society
   P.O. Box 722, Corvallis, OR 97339-0722

Project Check List and Sources for Materials and Equipment

The following check and source list was prepared by Scott Bettin (Bonneville Power Administration, PJW, Box 321, Portland, OR 97208-3621; 503-230-4982). Please note that prices quoted are for 1991.

PROJECT CHECK LIST AND SOURCES FOR MATERIALS AND EQUIPMENT

Tools and Materials

___ chainsaws
___ chainsaw file
___ extra chain
___ chainsaw winch
___ pulleys
___ choker
___ shackles (2 ton)
___ extra winch cables
___ grip hoist
___ grip hoist pins
___ wood drill
___ wood drill bits
___ 1" threaded rebar
___ 5 lb. sledge hammer
___ rock drill
___ rock drill bits
___ cable
___ cable clamps

___ ratchet set
___ glue cartridges
___ Mirafi cloth (700 mill)
___ chainlink fence
___ fencing pliers
___ staples
___ framing hammer
___ gas can
___ 2-cycle oil
___ air filters
___ shovel
___ pulaski
___ flat file
___ pry bar
___ field vest
___ 1/2" dowell rods
___ cable cutter
___

Safety Equipment

___ safety helmets
___ ear plugs
___ safety glasses
___ gloves
___ chaps
___ rubber boots
___ canteen
___ bladder bag
___ absorbent pad
___ oil boom
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Suppliers for Materials (* denotes 1991 additions to the list)

Rock Drills (diameters 1" or less)

BC Supply 7606 N.E. 11th Portland, OR 97211	(503) 289-5278	Ryobi ER 160 $550 Gas Powered Rock Drill Weight 12 lbs.
Hilti Fastening Systems 3487 N.W. Yeon Way Portland, OR 97210	(503) 227-6323	Model GP-22 $800 Gas Powered Rock Drill Weight 16 lbs.

Bits

Bosch bits are now on government contract number GS-06F-77959. Bit T3823 9/16" X 16" SDS are $18.06 ea. There are other sizes available. Your purchasing agent should have a copy of the catalogue. If not their address is:
Rober Bosch Power Tool Corporation (919) 636-4371
100 Bosch Blvd., New Bern, NC 28562-4097

BC Supply 7606 N.E. 11th Portland, OR 97211	(503) 289-5278	taper adaptor for Hilti $27.50 SDS 9/16" X 16 $27.50

Rock Drill (1" diameter or greater)

Pionjar Walter C. May Inc. Atten: Carl May 3665 Duford Rd., Sagle, ID 83860	(208) 263-3538	Cobra rock drill $4600 Weight 55 lbs.

If you are doing any pionjar drilling, Intraset drill steels are much better than the screw-on star bits. They have one cutting surface and are tough to get stuck. These steels are available through BC. Supply, 7606 NE 11th, Portland OR, 97211

Bit Retipping or Sharpening

Cal-Ore Carbide Inc. 2919 N. Pacific Hwy., Medford, OR 92504	(503) 772-2293	sharpening $5.80 retip $15.45
Carbide Saw & Tool Company 2337 Burnside Ave., Portland, OR	(503) 235-8060	

Project Check List and Sources for Materials and Equipment (continued)

Glue
Emhart Molly (215) 929-5764
Parafast Resin Mortar Cartridge
504 Mt. Laurel Ave., Temple, PA. 19560

Resin Mortar Cartridge
$15.88/cartridge

West Coast Distributor:
Portland Contractors Supply (503) 232-5173
122 SE 8th, Portland, OR 97214

Hilti Fastening Systems
(address listed above)

C-100 Cartridge

Cable
Rushing Rope & Wire Supply (503) 224-9127
2900 NW 29th
Portland, OR

1/2" galvanized cable
cut into 120' lengths,
no spool $.80/ft

Cable Cutter
Pell Cable Cutter Co. (208) 888-7571
Div. Morse Starrett Products Co.
184 NW 10th St., Meridian, ID 83642

Model W Hydraulic cable
cutter $350

Staples
Keystone Steel & Wire Company
7000 SW Adams St., Peoria, IL 61641
(800-635-7500 for dealer nearest you)

2-1/2" galvanized stockade staples
$30-65/50 lb box

Wood Drill & Bits
Stihl BT 310 Drill Attachment $159 ea.
2 replacement gears needed per drill. $22/ gear, part #4310-642-1000
wood drill bits 1" X 30" $21/bit stihl part # 4310-442-3800

* Stihl earth auger
It is purchased in three parts
1) BT-309 one man boring gear part# 4309-201-0201, $360 ea.
2) 08S power head part #1108-011-3015, $439.96 ea.
3) Boring head 4309-007-1005, $89.85 ea.

Bits for the auger are 13/16" x 29" Irwin Auger bits part # 47013
Everett Industrial Supply (206) 624-1610
2201 Pacific Ave., Everett, WA. 98201
(This drill is much, much, easier to use than the BT-310. Submitted by Doug Bakke:R06F05D01A)

* Gas Powered Winch
Lewis Products (503) 772-9646 Model 401 or 400 $575 w/cable
40 Belknap Rd., Medford, OR 97501

Lewis Winch with 3/16" X 150'cable. Have pressed eye at the end of cable, instead of a hook. Make connections with a 2 ton shackle (shackles smaller than that will break!). Have spare cables available. Key to efficient winching is proper care of the cable. Take the time to wind it properly on the spool each time. You must match the pitch of the chain to the power head being used. It has 8,000 lbs of pull which can be increased by using pulleys. Pulleys are available at most logging shops. There are some good ones from Japan that are usually orange and cost around $50 ea.

Model 400 fits all saws with 3/8" drive chains. Model 401 has a much better attachment system but only fits saws with drives on the outside.

Project Check List and Sources for Materials and Equipment (continued)

Hand winch (come-a-long)
Griphoist model TU-17 1 ton pulling capacity $465
C.H. Bull Co., 233 Utah Ave., S. San Francisco, CA 94080
(415) 871-8440

* Winch Strap
McMaster-Carr Supply Co. (213) 692-5911 $50 ea.
P.O. Box 54960, Los Angeles, CA. 90054-0960

These straps are used to wrap around a tree so as not to damage the bark while using it as a tail tree for one of your pulleys. They are polyester w/delta rings, 4"s wide, 27 or 30' lengths (wrap them around the tree several times).

* Mirafi cloth (700 mill) $1.50/sq.ft.
Oregon Culvert Co., Inc. (503) 692-0415
P.O. Box 398, Tualatin, OR 97062

This is used to seal small structures (typically channel-spanning weirs).

Technical Issues Related To Nonpoint Source Management

John P. Potyondy[1]

Abstract.--Nonpoint source pollution is one of the Nation's remaining water quality problems. Because of inherent differences between point sources and nonpoint sources, different control strategies are required. Nonpoint source control strategies rely primarily on the application of Best Management Practices (BMPs) as the means to achieve protection of designated beneficial uses. Increasingly, environmental groups and regulatory agencies are looking toward instream numeric water quality criteria as a regulatory mechanism for controlling nonpoint sources. Numerous technical problems exist with this approach. The most significant being the highly variable and poorly understood relationships between land use and the beneficial uses that need to be protected. The continued use of BMPs appears to offer important advantages over instream water quality standards and their continued use is suggested. In the long-term, monitoring data accumulated to evaluate BMPs can be used to build a sound scientific basis for eventual evolution to water quality based approaches.

INTRODUCTION

Passage of the Clean Water Act (CWA) in 1972 is generally regarded as the beginning of water quality management in the United States. In the Act, Congress established a national goal "to restore and maintain the chemical, physical, and biological integrity of the Nation's waters." The legislation is couched in laymen terminology such as "swimmable," "fishable," and "propagation of aquatic life." For regulators and technical experts, terminology such as "maintenance and enhancement of designated beneficial uses" are more commonly used although their precise meaning is often purposefully ambiguous.

Water pollution control is generally divided into two primary categories: Point sources and nonpoint sources. Point sources of pollution generally come out of a pipe. They are the effluent of discrete processing or manufacturing activities and are subject to direct end-of-pipe control. The quality of the water leaving a facility can be easily measured, the source is readily identified, and the responsible party is known. Regulatory control is accomplished by setting discharge standards through National Pollutant Discharge Elimination Permits (NPDES).

Nonpoint sources of pollution (NPS) are diffuse and result from diverse land disturbing activities such as agriculture, forestry, construction, resource extraction, urban runoff, hydromodification, and others. Pollution problems are the result of past and present land uses and the responsible party may be difficult to identify. Pollutants often come from many sources, travel numerous pathways to the stream, and the initiation of a pollution event is subject to storm events which are as unpredictable as the weather. Partially due to confusing regulations, control of NPS has proven to be more difficult than originally envisioned.

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Fisheries and domestic water are the designated beneficial uses of greatest concern to the public. Coldwater fisheries are generally regarded to be the most sensitive to forest management activities and an area of interest to much of the public, especially in the western United States. The body of knowledge about the interactions between land management and aquatic ecosystems has been reviewed in several recent publications (Salo and Cundy 1987; Chapman and McLeod 1987; MacDonald et al. 1991; Meehan 1991).

In spite of all we know, many believe that we lack the precise scientific knowledge needed to link on-the-ground management activities to coldwater fisheries or the biological integrity of aquatic ecosystems in the context of a regulatory framework. Others, fully recognizing the deficiencies of the available information, point out the magnitude of nonpoint source problems and the limited progress demonstrated to date, argue that it is time to change strategies and apply strict instream water quality criteria to protect and maintain existing beneficial uses. In the absence of scientific certainty, they conclude that it is best to err on the side of aquatic ecosystem protection instead of commodity users. To date, science has not resolved the conflict which is likely to become more emotional over the next few years.

On a national scale, progress has been slow. In forestry, few States have initiated regulatory (e.g., Oregon, Washington, Idaho, California, Alaska) or quasi-regulatory (e.g., Maine, Massachusetts, Nevada) programs which mostly rely on Best Management Practices (BMPs). As a result, environmental groups, professional societies, and some States are showing an increased interest in the establishment of numeric water quality criteria as performance standards. EPA's Nonpoint Source Agenda for the Future (EPA 1989) lists a national goal of having appropriate water quality standards, including fine sediment criteria for selected waters, adopted in all States by 1993. Within the Forest Service, the Colombia River Anadromous Fish Policy Implementation Guide contains a process which will establish *de facto* instream criteria, including sediment, as one way to measure progress aimed at protecting anadromous fish habitats.

HISTORY OF NONPOINT SOURCE CONTROL

Following passage of the Clean Water Act, the General Accounting Office estimated in 1986 that the Federal Government had spent $37 billion of CWA funds to assist municipalities in the construction and upgrading of wastewater treatment plants (GAO 1986). Surface water pollution from industrial and municipal point sources was thought to be largely under control. While the Nation's waters appeared to be getting cleaner as a result of CWA programs, it was difficult to precisely assess the benefits of point source controls due to natural background levels and NSP. The Environmental Protection Agency (EPA) concluded that NSP was among the leading causes of the Nation's remaining water quality problems (Thomas 1985). While sources varied for different parts of the country, agricultural operations were identified as the most pervasive nonpoint source. Silvicultural sources, contributions from urban areas, mining, and construction sites were identified as important sources that should be addressed by local areas.

The resulting passage of the 1987 Water Quality Act (WQA) by Congress, placed special emphasis on nonpoint sources by making it "the national policy that programs for the control of nonpoint sources of pollution be developed and implemented in an expeditious manner." Consistent with section 319 of the WQA, States were directed to identify those waters where water quality standards cannot be met without the control of NSP and to develop nonpoint source assessment and management programs which will serve as the cornerstone of the National nonpoint source program for the future. In addition, Federal consistency provisions of the WQA encourages States to establish processes to assure that Federal projects and activities do not conflict with the State's nonpoint source management program. Should a State determine that a proposed Federal action is not "consistent" with its NPS Management Program, the Federal agency must accommodate the States's concerns or explain in a timely manner why it cannot do so.

While the Water Quality Act of 1987 reaffirmed national interest in nonpoint sources, NPS problems even though given little attention in the original Clean Water Act legislation, were the focus of na-

tional interest by the mid 1970's. Strategies successfully used in the point source program, were applied to NPS problems. This was an unfortunate choice and was soon discovered to be an inappropriate strategy for a variety of technical reasons to be discussed in this paper.

NONPOINT SOURCE CONTROL STRATEGY

While the effects of pollution on beneficial uses are identical regardless of the source, programs designed for their control must be distinctly different. Point sources are effectively controlled by end-of-pipe treatments which regulate the release of discharges. Nonpoint sources can only be effectively controlled by prevention. In recognition of this and in the absence of specific Congressional direction or regulatory requirements, EPA initiated a NPS control strategy that relied on voluntary, nonregulatory approaches utilizing preventive practices, or Best Management Practices (BMPs), as the primary control mechanism to assure State water quality standards are achieved.

The Forest Service and other interests worked several years with EPA to develop a mutually acceptable and technically appropriate strategy for controlling nonpoint source controls and meeting water quality standards (Harper 1987; Solomon 1988). Guidance to implement the strategy is contained in Chapter 2 of the EPA Water Quality Standards Handbook. The strategy attempts to explain the complex relationship between land management activities, water quality standards, and Best Management Practices as they pertain to nonpoint source control programs.

The EPA nonpoint control strategy recognizes Best Management Practices (BMPs) as a prime means to achieve protection of designated beneficial uses. BMPs are not the only component of the strategy, however, and attainment of State water quality standards is the ultimate objective. Water quality standards are identified by each State and consist of two components and an additional policy: (1) the beneficial uses of the water, (2) numeric and narrative criteria, and (3) an antidegradation policy (EPA 1988).

Under this strategy, both BMPs and water quality criteria are the standard for evaluating the attainment of CWA goals. Cost effective and reasonable BMPs are applied in a manner designed to achieve water quality standards. After BMPs are applied, the States have primary responsibility to evaluate their effectiveness in protecting water quality through monitoring. If standards have been violated, the States and the responsible party take action to: (1) revise BMPs, (2) revise water quality standards, or (3) cease the activity. In implementing this strategy, many States have formalized BMPs in State regulations, such as forest practices acts, requiring use of specific BMPs for silvicultural activities. At the same time, States require adherence to water quality criteria as part of State water quality regulations.

At first it may appear that land owners (and land management agencies) are placed in double jeopardy under this arrangement. Once with respect to application of BMPs, and again with respect to attainment of water quality standards. In all fairness, the landowner should only be subject to one set of regulatory performance standards; either BMPs or instream water quality standards. For a number of technical and pragmatic reasons to be discussed later, the only appropriate performance standard is BMPs.

This does not mean that water quality standards are replaced by BMPs. Instead, water quality standards become the attainment measure by which BMPs are evaluated. They define the desired instream objective, or benchmark, specifying the amount of protection needed to fully protect specific beneficial uses.

For example, if State approved BMPs are properly applied and water quality standards are still violated, regulatory action would not be brought against the landowner. Rather, responsibility for not meeting the water quality standard is shared by the landowner and the State. Both parties would work together to identify the reason for the violation and devise additional practices which might be required to achieve the desired level of protection. Under this scenario, water quality standards are the benchmark for evaluating performance as part of the feedback loop concept (Figure 1).

In summary, BMPs are the performance standards used in regulatory programs and water quality standards are the attainment standards used to evaluate needed changes. A continual iterative process is used

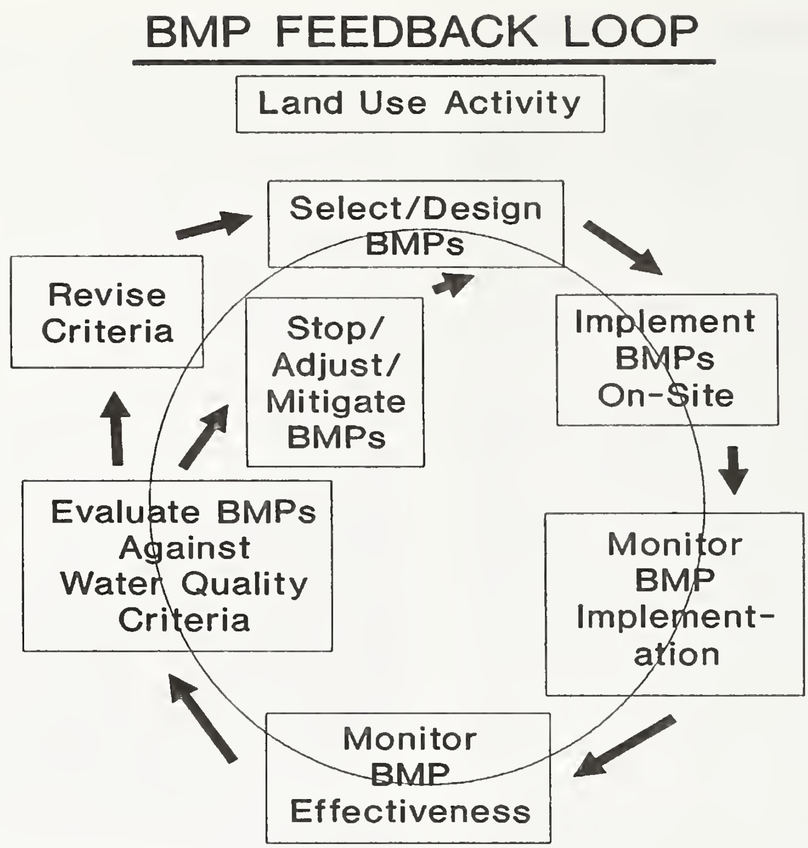

Figure 1. Best Management Practices feedback loop.

which progressively adjusts standards and practices until water quality is protected to the maximum extent feasible discussed in the original CWA legislation.

IMPORTANCE OF MONITORING

To a large extent the success or failure of the NPS strategy depends on monitoring (MacDonald et al. 1991). Monitoring has a direct bearing on such basis issues as whether or not water quality is limiting designated uses for a water body (water quality impaired) or if water quality standards are being met. Monitoring is also critical to evaluate first the implementation of BMPs and then their effectiveness. A critical part of the implementation feedback loop is the assurance that BMPs are properly integrated into on-the-ground land management. Finally, monitoring is needed to determine if water quality criteria are sufficiently and properly defined to protect beneficial uses.

Implementation monitoring is the most common and least technical form of monitoring. Its primary aim is to see if BMPs and forest practices rules were properly applied. Generally no measurements of water quality are made, although review teams may qualitatively evaluate management impacts on streams. Based largely on qualitative observations, review teams normally make recommendations regarding specific management practices and their improvement (Bauer 1985; Giles 1991).

Effectiveness monitoring is done to determine if practices were effective in controlling pollutants to planned levels. This is done on a sample basis selecting representative projects and usually involves detailed field measurements. For many BMPs, on-site monitoring outside of stream channels is adequate to properly evaluate impacts without the confounding influence inherent with instream measurements. The work of Swift (1986) where he evaluated filter strip designs and characteristics is an example of onsite effectiveness monitoring. Effectiveness monitoring

can also include biological indicators and physical surrogates for beneficial uses, such as cobble embeddedness or substrate composition. This approach generally evaluates combinations of practices applied at the watershed level. The work of Potyondy (1989) where he evaluated cobble embeddedness with respect to management activities within watersheds on Boise National Forest streams is an example of instream effectiveness monitoring. Regardless of the design, several iterative cycles are normally needed to establish and refine BMPs to acceptable levels of performance using the feedback loop concept.

Validation monitoring is the most intensive form of monitoring and is directly applicable to the establishment of water quality criteria. In most cases, validation monitoring is conducted by researchers utilizing permanent plots and long-term studies. The objective is to test: (1) whether water quality criteria limits are sufficient to protect beneficial uses, or (2) whether a selected criterion is an appropriate surrogate to protect beneficial uses. By documenting the changes in physical habitat (e.g., bed material particle size, turbidity, temperature) and the effect this has on designated uses (e.g., coldwater fish populations) the basis for the establishment of water quality criteria can be set based on firm scientific data.

TECHNICAL PROBLEMS WITH INSTREAM CRITERIA

Many technical issues need to be overcome before instream criteria can be established with respect to forestry and beneficial use protection and used for regulatory purposes.

Lack of Criteria Appropriate to Forest Management

Water quality standards were initially developed for control of point sources of pollution. Consequently, most criteria are either insensitive or irrelevant to forest management activities. Only five or six criteria (dissolved oxygen, turbidity, suspended solids, color, temperature, and perhaps nitrate-nitrogen) of more than 100 listed in EPA's "Gold Book" (EPA 1986) are affected by forest management (MacDonald et al. 1991). Other parameters of significance to aquatic ecosystems and fisheries (e.g., intergravel dissolved oxygen, cobble embeddedness) have been identified and are being considered as water quality standards by some States (Harvey 1989). The technical basis and widespread testing of their geographic applicability has yet to be confirmed. A recent review of salmonid-habitat relationships in the western United States (Marcus et al. 1990) examined many of the existing water quality criteria and concluded that they did not apply well to these streams.

Criteria Based on "Best Guess"/Point Source Philosophy

Current water quality standards were largely developed for static point source situations. The CWA required that States develop standards within a specified time frame. Not much thought was given to nonpoint sources. The prevailing thought and direction was to make "best guess" estimates and worry about changes during subsequent reviews required by the CWA (Harper 1987). This approach ignored the realities of dealing with sensitive environmental issues since it is extremely difficult to change existing standards found to be inappropriate, particularly if the result is a lowering, or apparent weakening, of the standard.

Criteria Developed from Laboratory Studies

The laboratory conditions used to establish many water quality standards are not representative of the diversity and complexity found in natural stream systems. Field response of fish for example, is not always the same as that predicted by laboratory experiments. For example, fish may avoid adverse temperature fluctuations by seeking out groundwater seeps or cool tributary inlets and thereby survive temperatures thought to be lethal (Ice 1989). With respect to sediment, laboratory studies have demonstrated consistent negative effects of sediment on growth, emergence and survival of fish. Field studies, however, have not produced similarly consistent results primarily due to the introduction of confounding environmental effects in natural setting and our inability to isolate them (Everest et al. 1987, Chapman and McLeod 1987).

Problems with Background Variability

NPS pollutants are distinctly different from point source pollutants in that NPS pollutants occur in the natural environment. For a typical NPS pollutant, such as sediment, there is a base level of natural sediment plus some accelerated amount resulting from human activities. By contrast, the base level of a human-made toxic pollutant found in natural waters is zero. Separating the anthropogenic from the natural can be difficult especially since precise measurement of sediment, regardless of its source, is a technically difficult task. In addition, the availability of undisturbed watersheds of approximately comparable size and within similar geologic settings to serve as controls is severely limited to nonexistent.

High Complexity of Natural Systems

Three elements of natural variability need to be addressed: hydrology, site, and vegetation (Ice 1989). Hydrologic variability encompasses water quality conditions resulting from hydrologic events including peak flows, time since last storm event, discharge rates, and position on the hydrograph rising or falling limb as well as effects from episodic and seasonal conditions (wildfire, leaf fall). Site variability includes geology, soils, and geomorphology as they effect water quality response. Vegetation variability considered the type and age distribution of vegetation within the watershed. Because of the diversity of natural landscapes and the different processes operating in each, an unlimited number of combinations is possible.

Problems Dealing with High Natural Variability

Most of the criteria affected by forest management activities are sediment-related. The current state of knowledge about sediment production from forested watersheds in managed and unmanaged conditions and the movement of sediment through stream systems exhibits large temporal and spatial variation and is poorly understood (King 1992). Existing criteria have not adequately recognized the limited precision possible in the science of monitoring NPS water quality and have not allowed for the full range of natural variance found in streams. The variability of turbidity, suspended solids, and bedload measurements and measurement difficulties are well documented in the literature (MacDonald et al. 1991). Many of the existing water quality standards related to temperature, dissolved oxygen, turbidity, and other variables are often exceeded even in undisturbed streams (Beschta and Ice 1990). Additional factors involving scale and uncertainty of sediment monitoring have only recently been recognized (MacDonald 1992). The problem of detecting change through monitoring is intensified given the variability introduced by dilution effects, storage effects, and measurement error.

High Cost of Monitoring

Because human-caused water quality conditions in forested watersheds are so masked by extremely variable natural and background conditions, monitoring that accurately detects the true water quality condition requires intense, long-term studies. The Bull Run Watershed near Portland, Oregon serves as an example of a forested watershed where water quality standards are being used to directly assess forest management effects. The current water quality of this municipal supply watershed is so high that sediment filtration is not needed. Annual monitoring costs for this one watershed are estimated to be about $500,000 (Ice 1989). Routine application of this level of monitoring to a wide number of watersheds would obviously be prohibitively expensive.

Link Between Land Use and Beneficial Use is Poorly Understood

As has been pointed out previously, water quality criteria relevant to forest management are sediment-related and coldwater fisheries is the beneficial use of greatest concern. Consequently, sediment and its relation to fisheries is of great interest. It is generally agreed that our knowledge about sediment-fish interactions is incomplete. The published record shows that researchers have not successfully developed useful predictive relationships between fish populations and alterations of their environment by sediment (McIntyre 1992). In a 1987 review of sediment criteria funded by EPA, Chapman and McLeod (1987) examined the relationship between sediment and the effect it has on the biology of the fish. They concluded:

> "We found no functional predictors that would serve environmental regulators in evaluating quantitative effects of sediment on the natural incubation, rearing, or wintering phases of salmonid life history in the northern Rockies."

The authors suggest that every system should be analyzed as a discrete unit and managed based on the best available scientific judgement with managers favoring conservation of the fisheries resource in light of existing uncertainty.

The more holistic analysis of the current situation is summarized by Everest et al. (1987):

> "The capability of a stream to mobilize and transport fine sediment is highly variable and dependent on numerous physical factors, which can vary from reach to reach within the same basin. This level of variability makes it practically impossible to develop useful universal guidelines or criteria for protecting stream biota from turbidity and fine sediment. Past establishment of such guidelines stemmed from the assumption that any sediment entering streams as a result of land management had negative effects on aquatic biota. In any situation, this assumption might or might not be true."

The evident conclusion is that based on our present understanding and information, environmental regulators are currently without reliable methods to assess the quantitative effects of sediment on stream salmonids. It would appear obvious that the technology does not exist to establish instream sediment criteria at this time.

That unanimous opinion however, was not echoed by scientists invited to attend a joint EPA/Forest Service Technical Workshop on Sediments (Feb. 3-7, 1992, Corvallis, Oregon). Discussions among the participants indicated that, in general, physical scientists thought the current state of technology was such that we do not presently have technology with the precision and accuracy to establish criteria. In contrast, biological scientists generally felt variability was not much of a problem and that it could be dealt with satisfactorily in the establishment of criteria. These divergent viewpoints may be indicators of why progress in developing links between land management effects and the biological consequences has been so slow.

The development of instream criteria may in reality be more a political exercise than a technical one in that it involves value judgements. Involved are questions about who bears the cost if criteria are incorrectly specified; commodity users or the environment. Some would elect to err in favor of fish, others might choose economic interests over environmental protection, while purists might desire a higher degree of scientific certainty before making any judgments. Ultimately these are political questions which must be dealt with through existing institutions.

ADVANTAGES OF BMP APPROACH

The current NPS strategy of relying primarily on BMPs as the control mechanism for nonpoint source pollution evolved not so much as a result of the recognized deficiencies of using instream water quality standards, but rather because the BMP approach appears to work well. NPS assessments have been conducted by a number of states to determine the effectiveness of forest nonpoint source programs and State BMPs for forest management activities (Ice 1987). Assessments conducted in Oregon, Washington, California, Idaho, and Montana as well as other states all show that most water quality problems are avoided if BMPs are properly applied (Ice 1989).

BMPs have the following advantageous attributes:

1. A large body of knowledge is available that can be used to establish appropriate land management practices. Practices can be easily tailored to fit the diverse site specific conditions encountered in the field including soils, topography, geology, vegetation, and climate.
2. Practices can be designed to protect beneficial uses while incorporating concepts of risk and feasibility. Risk is important because it recognizes that some projects will fail to meet an absolute standard under extreme natural conditions. Feasibility is an important concept which recognizes that absolute control at all costs is not possible or desirable. The test of feasibility includes political, social, economic, and technical aspects. The number or the intensity of BMPs to be applied in particular

situations can be customized to fit the importance of the beneficial uses requiring protection.

3. Monitoring of BMP effectiveness is relative simple compared to monitoring of instream criteria. It is relatively easy to document misapplication or the absence of BMPs. Visual inspection is often adequate for many BMPs to see if they are working properly. Once problems are identified, it is easy to change management practices to correct the situation.
4. The benefits of BMP implementation or failure are readily understandable by field personnel. Because of this, it is easy to communicate necessary changes to the people doing the work in the field and gain understanding and support for needed improvement. 5. Most importantly, BMPs are preventive rather than curative measures. Beneficial uses are most practicably and efficiently protected by using a BMP process which prevents pollutants from leaving the source through careful site specific planning, design, and implementation of BMPs **before** activities take place. Compliance is based on surveillance and enforcement of how BMPs were applied. Compliance checks which depend on attainment of instream criteria are after the fact. Because of the nature of land disturbing activities, it may not be possible to correct an unacceptable situation or clearly identify the source of the problem. Little environmental protection is provided by citing an individual for violating water quality standards after the damage is done.

SUMMARY

The Clean Water Act established an objective of restoring and maintaining the Nation's waters. Point source problems have largely been solved and greater emphasis is now being given to the control of nonpoint source pollution. Technical considerations require development of management strategies for nonpoint sources which are distinctly different from point source controls. EPA has devised a strategy relying on preventive land management practices (BMPs) as the primary mechanism to achieve protection of beneficial uses. Nevertheless, the agency continues to move toward water quality standard based approaches in attempting to address emerging nonpoint source issues such as Total Maximum Daily Loading or TMDL, and coastal zone management, ignoring or downplaying the technical difficulties associated with instream criteria.

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Approaches To Solving Nonpoint Source Issues

George G. Ice[1]

Abstract.--Numerous difficult nonpoint source issues are currently being addressed by western state agencies using innovative approaches. Issues include managing for cumulative effects, how to cooperatively manage in mixed-ownership watersheds, development and monitoring of load allocations for nonpoint sources, revisions to nonpoint source control programs, assessing BMP effectiveness, and application of antidegradation water quality standards. Many of these issues present nearly intractable technical or social difficulties. A number of special approaches are being followed by states to address these concerns. These include: panels of experts, detailed decision strategies, adaptive management, interdisciplinary team assessments, cooperative watershed planning, and focused forest practice regulations.

INTRODUCTION

Early in the development of state nonpoint source control programs a model forest practices act was proposed. Instead, it was decided that programs should utilize existing state forestry infrastructures to develop their own unique programs. While this has led to uneven levels of program success, it has also fostered diverse solutions and approaches to addressing the difficult technical, economic, and social problems connected with nonpoint source controls.

Problems can be divided into three types: tame, messy, and wicked. With tame problems there is general consensus on what needs to be done and how to accomplish it. For messy problems there is again general consensus on what needs to be done but the solution is not obvious and may have adverse side-effects. For wicked problems there is usually agreement that there are problems but consensus on neither the desirable outcomes nor mechanisms for achieving those outcomes. It seems that most problems in forest nonpoint sources are either messy or wicked.

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OREGON

Rule Changes and Board of Forestry Forum

Since 1972 the silvicultural nonpoint source control program in Oregon has been based on the Oregon Forest Practices Act and rules. These rules have undergone extensive review and modification since 1982. The Oregon Department of Forestry (ODOF) has sponsored several reviews to determine the effectiveness of the forest practices program. The first formal review of the forest practice program in 1977 involved both field visits and questionnaires (Brown et al. 1977). A series of formal and informal reviews has continued by ODOF and Oregon Department of Environmental Quality (ODEQ). State forest practice records for 1989 indicate 97 percent compliance with the forest practice rules (citation not issued) (ODOF, 1990). The state has developed a detailed monitoring program to address special concerns about forest chemicals, riparian zone rules, landslides, and impacts to municipal water supplies.

During the winter of 1981-1982, localized torrential rainfalls in the Oregon coast resulted in numerous debris avalanches. In response to these events, a Soils Task Force developed a report to the state forester on Minimizing Debris Avalanches on Forest Lands (Spiesschaert et al. 1982). Following lengthy review,

new forest practice rules were adopted which provide for identification of high [landslide] risk areas (regions) and sites. Written plans are required for high risk sites that threaten fish-bearing streams. New rules were adopted for roads in high risk areas. A similar process was followed in the development of new rules for riparian areas in 1987.

In 1987, the Oregon legislature again revised the Forest Practice Act to avoid conflicts between state land-use laws and the state forest practice program. Changes were made in the make-up of the Board of Forestry and certain lands were identified as sensitive. Under HB3396, the Board of Forestry was required to develop inventories for: (1) threatened and endangered fish and wildlife species; (2) sensitive bird nesting, roosting and watering sites; (3) biological sites that are ecologically and scientifically significant; and (4) significant wetlands. Where forest practices conflict with these resource values, appropriate levels of protection (new rules) will be developed. Technical and policy committees have developed many of these inventories and rule revisions.

In December 1990, the Oregon Board of Forestry (OBOF) hosted a forum to hear concerns about the Forest Practices Program. Twenty-one separate issues were identified, including eight water quality/fisheries issues: (1) classification and protection of waters of the state; (2) declines in the salmon fisheries of the Oregon South Coast; (3) landslides; (4) special consideration for municipal and domestic-use watersheds; (5) application of pesticides; (6) biodiversity/new forestry; (7) cumulative effects; and (8) monitoring. The ODOF, faced with this avalanche of technical issues, has developed a strategic issues workplan which extends into 1997.

At the same time as the OBOF forum, the industry successfully sponsored a bill (SB1125) which required new rules on: maximum clearcut size (120 acres), accelerated reforestation (begin within 12 months), and harvesting along scenic highways. It also required that studies on cumulative effects and the role of forest management in salmon declines be done. In a departure from earlier legislation, SB1125 required specific rather than general modifications of the rules. This brief review of the changes in the Oregon Forest Practice rules shows a very dynamic process. No one who has been involved in these changes would question that the technical, social, and economic problems have been "messy" and "wicked." Changes in the rules have resulted from public concerns expressed at OBOF hearings, technical task force finds, general guidance legislation, and legislation with specific rule changes. There is a perception that states are unwilling to develop effective nonpoint source control programs and that revisions in the Clean Water Act are needed to achieve effective programs. At least for western states, there is tremendous pressure within the states for review and improvement of the forest practice programs. Programs remain dynamic.

Tualatin Total Maximum Daily Load for Forestland

The Oregon Department of Environmental Quality (ODEQ) has identified several stream segments in Oregon as water quality limited based on existing information. In 1986 the Northwest Environmental Defense Center (NEDC) filed a complaint alleging that EPA had violated section 303 of the Clean Water Act (CWA) by failing to develop Total Maximum Daily Load (TMDL) limits for water quality limited streams in Oregon. TMDL limits are designed to reduce management loading to levels which will not reduce beneficial uses. In July, 1987 a consent decree was agreed to which required that ODEQ develop TMDL limits for water quality limited water bodies. A list of 11 water bodies was developed which will have initial TMDL planning. The first of these stream segments to have TMDL planning is the Tualatin River.

The TMDL process is an example of a "messy" problem where there is general agreement in the desired outcome (protection of beneficial uses) but no agreement on how to achieve that goal. The Oregon Department of Forestry (ODOF) and six other agencies submitted plans to address excess phosphorous loadings in the watershed (ODOF 1991). There continues to be much debate between the ODOF and ODEQ about the appropriateness of load allocations for forest management. Forest management is a small contributor (about 5 percent), background and management contributions are difficult to distinguish, and the existing forest practices rules exceed the voluntary controls for larger contributors such as agriculture. ODOF was placed in a difficult position. It recognized that nonpoint sources need to be controlled in a water-quality limited watershed, but water-quality experts indicated that forest management had little if any impact on phosphorus levels. An effective compliance monitoring program would be costly to imple-

ment; straining scarce resources needed for other higher-priority problems. Also, ODOF was reluctant to agree to load allocations for forest lands where estimate errors might indicate future loading violations with no management solutions. Two innovative approaches resulted from the concerns of ODOF and the BOF. First, a technical specialists panel was convened which reviewed the modelling and monitoring programs in the basin and provided guidance about the role of forest management in contributing to excess phosphorus. This panel has served as a technical mediator between the ODOF and ODEQ. Second, a formal decision tree was developed by ODOF staff which guided the monitoring and control programs for the basin. The decision tree required more expensive compliance monitoring and changes in the basin forest practice rules only if an extensive literature review by Oregon State University (Salminen and Beschta 1991) indicated the likelihood of phosphorus impacts from forest operations, or if monitoring of forested subbasins indicates negative water quality trends.

WASHINGTON

Timber/Fish/Wildlife Agreement

For "wicked" problems, there is no agreement on the final objectives or solutions. One approach to address "wicked" problems is to force consensus on goals and the decision process. In Washington, by the mid-1980's the number of court cases and political confrontations between environmental groups, Indian tribes, and the forest industry had become counter-productive to all sides. A mediated agreement, known as Timber/Fish/Wildlife (TFW), was reached in 1987 between state agencies, Indian tribes, the timber industry, non-industrial timberland owners, and environmental groups (Halbert and Lee 1990). TFW was designed to resolve environmental conflicts through an ongoing process of adaptive management.

TFW has several key features. It set goals for water quality, wildlife, fisheries, cultural and archeological values, and timber. "Each TFW participant recognizes that the goals of all parties are equally as legitimate and important" (Rochelle and McDonald 1989). Key TFW elements included: (1) new riparian protection rules; (2) the use of alternative management approaches when they provide equal or better resource protection; (3) use of interdisciplinary teams to provide guidance where there is a potential for significant resource damage; (4) voluntary elements including Upland Management Areas (UMAs) for wildlife habitat, and Resource Management Plans for landscape/watershed scale planning; (5) pre-planning reviews of future activities for major landowners; (6) research and monitoring to achieve adaptive management goals; and (7) ongoing overall program monitoring.

An important component of the TFW agreement is the research program which is designed to address disputes through information. This research is coordinated through the Cooperative Monitoring, Evaluation, and Research (CMER) Committee. A feature of the TFW program is that representatives of each of the major groups is active at every level of the process. This means that committees working on technical questions have members from agencies, tribes, industry, and environmental groups.

Review of Rules for Forest Chemicals

One of the most important questions that the TFW program and CMER faced was the impact of forest operations on water quality and fish habitat. A research committee, the Water Quality Steering Committee (WQSC), was established under CMER to address questions about water quality protection. One of the primary questions the WQSC must address is: How effective are the current forest practice rules for chemical applications in protecting water quality and stream organisms? In 1987-1989 the WQSC supported several projects to investigate aerial applications of forest fertilizers and the biological significance of those applications. Based on the experience of these studies the WQSC developed recommendations and changes in the forest practice rules for fertilizer applications.

In 1989 the WQSC began planning for studies to assess the water-quality protection provided by forest practices rules on herbicides, insecticides, and other important pesticides. The WQSC identified four component questions it needed to address: (1) What are biologically significant concentrations of commonly used forest chemicals in streams?; (2) What application practices can be used to minimize introduction of chemicals to streams?; (3) What is the degree of compliance with the forest practice rules?; and (4) Are chemicals getting into forest streams and can we effectively monitor their introduction? A project was designed or identified to answer each of these component questions.

The WQSC has completed monitoring of seven sites. Results indicate that all sites had concentrations below the levels considered biologically significant but all sites had at least some chemical detected. As a classic "wicked" problem, these results are being interpreted differently by the varied members of the WQSC. Some suggest that any chemical introduction to a stream is a violation of the label. Other argue that drift is not considered an introduction and that the rules are meeting their objectives by keeping concentrations very low.

Screening Forest Practices

Agencies have insufficient funds to address in detail the numerous water-quality questions posed by all forest operations. Fortunately, the hazards and risks associated with different sites and operations are not the same. This represents the "messy" problem of determining just where to conduct a detailed assessment. Washington has moved toward procedures that allow state agencies to screen for those practices that create the greatest potential for significant environmental damage. An example is a screen prepared for application of forest chemicals. Under the Washington Forest Practice Act, a Class IV special practice must complete an environmental checklist in compliance with the State Environmental Policy Act (SEPA) and SEPA guidelines. A key has been developed which uses general toxicity information and resource risk to determine which types of spray operations will be considered to pose significant risk. Another consequence of this screen is that it forces operators to choose application conditions or chemicals to avoid being classified as a Class IV special operation.

Cumulative Effects

Another "messy" problem is cumulative effects. Development of workable cumulative watershed effects assessment methods for forests has been difficult because of the lack of critical technical information (i.e., routing methods), variability of site conditions, and differences in management perspectives. Washington is currently developing a team assessment approach to conduct basin analysis for cumulative effects. Assessments will be in Watershed Administrative Units of between 10,000-50,000 acres. Qualified teams, including members with skills in forestry, forest hydrology, forest soil science or geology, fisheries science, geomorphology and other necessary disciplines, will conduct assessments at a screening level or more detailed level if necessary. Assessments are conducted to identify the likelihood of adverse change and delivery of material to the stream (hazard) and the vulnerability of the system (risk). Assessment techniques, including a draft method to assess channel damage from increased flows, are being developed to aid in basin analysis. A team of field managers is responsible for developing prescriptions to address identified combinations of watershed/management hazard and resource risk. The management team will include one or more persons qualified in forest resource management, forest harvesting and road system engineering, forest hydrology, fisheries science or management, and other necessary disciplines. The idea is to identify practices that are appropriate at different locations in the basin (known as conditioning of practices). Any landowner with at least 10 percent ownership in a watershed can sponsor a watershed analysis. The advantage to a landowner is a simplified approval process for practices in watersheds that have received basin analysis.

CALIFORNIA

Sierra Accord, Grand Accord, and Emergency Rules

An example of a "wicked" problem that got more wicked is the Sierra Accord, Grand Accord, and Emergency Rules in California. In 1990 a comprehensive environmental initiative known as "Big Green" was narrowly defeated. To avoid a costly and potentially damaging new environmental initiative aimed directly at forestry, Sierra Pacific Timber Co., the largest forestland manager in California, and the Sierra Club, the premier California environmental group, entered into negotiations on a wide range of potential modifications to the forest practice rules. Important elements of the Sierra Accord included sustainability of forests and wildlife/old growth habitat protection. Watersheds and cumulative effects were generally treated through limits on the level of harvesting in a basin. This agreement met opposition by other forest companies and environmental groups and died. But, it spawned a set of bills called the "Grand Accord"

designed to use the ideas in the Sierra Accord. The Grand Accord bills were vetoed by the governor. The Board of Forestry (BOF) chose to implement as much of the Grand Accord as it could legally through adoption of emergency rules. Lawsuits challenged the legality of these emergency rules, arguing that no emergency had been demonstrated. The court ruled in favor of these challenges, restraining the BOF from implementing the emergency rules. The BOF and California Department of Forestry (CDF) are now going through the process of developing permanent rules which are targeted to be in place by January 1993. The lesson of this episode is that when controversial issues (wicked problems) are being addressed, broad coalitions need to be formed. No single portion of a group, no matter how powerful or well-intentioned, can control the groups response.

Managing Mixed-Ownership Watersheds

Basin cooperation in mixed-ownership watersheds is one of the most difficult problems state and federal agencies must address. This is another "messy" problem where there is often no agreement on the final goals. An unpublished survey by Megahan of cumulative effects methods, found that 85 percent of those responding had to deal with mixed-ownership watersheds but only 20 percent invited the other landowners to participate in the analysis (Megahan, 1992). The CDF and Fire Protection is currently sponsoring two pilot projects to establish methods of cooperative watershed planning and management in mixed-ownership watersheds. Objectives of the projects in the Scott River Basin and Mokelumne Watershed are to: (1) assess current and future land-use practices, (2) understand cumulative watershed effects, (3) develop cooperative planning methods, (4) identify impact mitigation techniques, and (5) establish ongoing monitoring.

The Mokelumne Watershed has provided considerable conflicts. Runoff from the watershed is used by the East Bay Municipal Utility District (EBMUD) to serve 1.1 million customers. In the upper portion of the basin major landowners are Georgia Pacific and the Forest Service. Georgia Pacific temporarily accelerated harvesting after acquiring the property, precipitating concerns by EBMUD about cumulative effects. Policy and technical committees have been meeting since 1989 to develop information and strategies on how to manage the watershed to address all concerns. Special subcommittees on roads and watershed monitoring have been active. As a result of these activities, Georgia Pacific has taken a number of corrective steps including: road inventories and corrective actions for identified "sores", road closures and gating, voluntary early adoption of the updated CDF cumulative effects assessment procedures, reduction in harvest levels, and full cooperation with the committees and with monitoring plans. EBMUD has sued CDF for not adequately addressing cumulative effects. Despite these disagreements, plans continue to establish a nested monitoring program in the basin to determine the sources of sediment and quality of the water. There is some hope that the cooperative effort in the basin will aid in the settlement of the lawsuit.

IDAHO

Antidegradation

Antidegradation or nondegradation standards are required as part of state water quality standards. For example, the antidegradation standard for Oregon states that "...existing high quality waters which exceed those levels necessary to support propagation of fish...shall be maintained and protected unless the Environmental Quality Commission chooses...to lower water quality for necessary and justifiable economic and social development." In 1981 staff of the Nez Perce National Forest predicted a 10 percent decline in cutthroat trout from planned development of a roadless area (McGreer 1989). This precipitated a lawsuit against EPA and two attempts by the Idaho Legislature to modify the Idaho water quality standards. These attempts were vetoed by the governor.

In 1988 a negotiated settlement was reached through the Northwest Natural Resources Center. Under this agreement, stream segments of concern are identified where protection above the current forest practice rules may be required. "Local working committees identify watershed goals, review land management plans and objectives, and identify on-the-ground actions needed to achieve water quality and fishery objectives" (McGreer 1989). The Idaho

Department of Lands (DOL) works with landowners to develop specific BMPs for stream segments of concern. Another category, Outstanding Resource Waters, will have special protections.

The DOL has completed the first round of work on stream segments of concern. More stream segments of concern were identified than expected, which created a tremendous work load for DOL staff. One of the strategies DOL is now undertaking is to look for commonly requested BMPs for stream segments of concern and adopt these into the general state forest practice rules.

MONTANA

Riparian Forest Practices Act

Until recently, Montana had a nonregulatory BMP program for forest nonpoint source control. BMPs were adopted and endorsed by the Montana Logging Association, Water Quality Board, and State Forestry Department. HB678 required that forest landowners and operators notify the Department of State Lands prior to conducting forest activities on private lands. The notification was designed to allow the state to send information on BMPs and provide technical assistance for sensitive watershed conditions. An aggressive educational program was promoted by key forestry groups, and MOU's were prepared to address specific problems such as cumulative effect planning in mixed private and USDA Forest Service watersheds.

Despite these cooperative and educational programs, an audit conducted in 1990 showed that BMPs were still not being used in some situations and there might even be a decline in performance since an audit in 1988. Influenced by these results, a focused state law, the 1991 Streamside Management Act, was passed with seven "don'ts" for streamside zones. In the streamside zone, operators are not allowed to broadcast burn, operate equipment (except on roads), clearcut, construct roads (except to cross a stream or wetland), handle chemicals, side-cast road material, or deposit slash in the stream.

Other states with nonregulatory programs have found good compliance with most BMPs but poorer performance for streamside BMPs. This very focused regulatory program is an interesting experiment to achieve good compliance while limiting the program scope and costs.

CONCLUSIONS

If we think that watershed problems have already been solved or will be solved in the next few years just look at the Oregon Department of Forestry workplan for forest practice issues. Work is scheduled to extend into 1997. We need to take advantage of the opportunities provided by the many diverse state programs and nonpoint source control strategies to test and develop new tools for nonpoint source control in the future.

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The National Riparian Strategy

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Abstract.--In 1989 James Overbay, Deputy Chief for National Forest Systems commissioned Regional Forester Gary Cargill to lead a National effort to make riparian area management a prominent part of the on-going forest planning and management process. The approach involved: (1) developing an integrated approach to implementing riparian standards and guidelines; (2) setting national, regional and forest goals for on-the-ground accomplishment; (3) using an integrated basinwide approach to accomplish priority goals with demonstration areas on every district; (4) conducting an inventory of current riparian ecological conditions; and (5) building increased internal and external support for the Forest Service Riparian effort. Positive on the ground actions by manager, specialists and users provide the best chance for restoring the function and value of existing Riparian Areas.

HISTORY

The Forest Service has been concerned about "securing favorable conditions of flow" from the National Forest Reserves since the passage of the Organic Act in 1897. There was early recognition that the condition of tributary watershed including riparian areas influences our ability to provide favorable conditions of flow.

The Multiple Use Sustained Yield Act of 1960 focused on riparian and stream concerns through the identification of water influence zones and related travel influence zones. These zones essentially described the larger riparian areas and assumed their protection by providing coordinating requirements to protect essential riparian values.

The National Forest Management Act of 1976 focused additional attention specifically on Riparian Areas and Chief of the Forest Service, John R. McGuire (1978), outlined some of the key elements that formed the basic policy at the 1978 Callaway Gardens Symposium in his address entitled "A Riparian Policy for Changing Times." Growing public interest during the 1980s and increasing management concerns about riparian values and health prompted the formation of a Washington Office team and the development of a National Riparian Strategy.

STRATEGY

A national meeting in Albuquerque, New Mexico in 1990 provided a forum for the discussion of riparian area needs, concerns, and goals from a variety of internal and external speakers. Each Forest Service Regional Team worked on tailoring an appropriately focused Regional Strategy for adoption by the Leadership Team that would support the National Strategy reprinted below:

"A STEWARDSHIP STRATEGY - CARING FOR RIPARIAN

Issue: Riparian areas are the most diverse and productive sites on many forests and rangelands; yet many riparian areas are in a depleted condition. This hinders our ability to fulfill our mission of caring for the land and serving people.

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Situation: Riparian areas comprise a small percentage of the land base of the National Forest System. Yet the variety of their dependent resource values and uses belies their small area. They are the key to productive fisheries and wildlife habitat, diversity of scenery and recreation sites, flood reduction, quality water for downstream users, continuous recharge of ground water, timber productions, and sustainable forage production. These beneficial uses and values depend heavily on healthy riparian conditions; conditions that also provide a good indication of the overall health of the land and its resources. Improving the productivity of these highly valuable areas requires wise and consistent resource management.

Many riparian areas currently fail to meet Forest Plan standards. This affects both, the continued production of resources and the ecological benefits that healthy riparian areas provide. The future capability of riparian areas to support all the uses desired and expected by the public depends on management actions to restore healthy conditions. The Forest Service has the knowledge and technology to make needed improvements. Opportunities are available to accomplish some needed work through cost-sharing and partnerships.

The rate at which we can improve riparian areas depends on a combination of commitment and funding for on-the-ground accomplishment. Sustainable riparian improvement will require the use of an integrated resource management approach that comprehensively addresses the long-term effects of all activities that occur within a watershed basin. The immediate results will be increased benefits to water quality, fish, wildlife, forage, recreation, and a quality environment. It will also demonstrate the values of best management practices. Leadership at all levels of the organization must affirm their support for healthy riparian areas in word and deed. The Forest Plans make a strong commitment to the public. We need to develop a strategy to achieve those commitments.

Strategy:

1. Develop an integrated approach to implementing Forest Land Management Plan riparian standards.
2. Set National, Regional, and Forest goals by June, 1990 for on-the-ground accomplishments. An example is to meet Forest Plan riparian condition standards by the end of the planning period.
3. Use the Forest Plan implementation and amendment process to establish a priority action program in each Region for improving riparian conditions through integrated resource management of whole watershed basins. Begin demonstration projects in each Region by FY 1990, on each Forest by FY 1991, and on all Ranger Districts by FY 1992.
4. Conduct a comprehensive inventory of riparian areas and their ecological condition for key resource uses and values by the year 1995.
5. Develop broad-based support for a strategy that energizes, promotes innovation, supports entrepreneurial spirit, builds on success through networking, provokes appropriate change in conventional wisdom, and recognizes those that accept the challenge."

ADJUSTING ATTITUDES FOR SUCCESS

The success of this Strategy depends on individual efforts guided and supported by Management. In many cases, changes in perceptions and attitudes vitally influence the successful application of the strategy. The following points identify key attitude shifts needed for success.

Action vs Study

Many obviously deteriorated riparian condition problems need correction. We have the knowledge in most cases to significantly improve the conditions through adjustments in the way we manage riparian uses in these situations. Further detailed study merely delays and defers needed action.

Leadership vs Technical

We currently have the technical ability to improve riparian conditions. More emphasis needs to focus on gaining management commitment and priority for taking needed actions to improve riparian conditions.

Corporate vs Functional

Management actions for healthy riparian condition must be accomplished across the board. Success will depend on an effective, integrated, interdisciplinary-team approach. It is a Forest Service corporate issue not merely a Range, Fisheries, or Hydrology task.

Wise Use vs Non-Use

Riparian areas have many values and significant productive potential. Use of resources should occur to the extent that long term harm does not accrue to riparian health or riparian dependent resources. Prohibiting all uses and activities limits opportunities to make needed improvements.

Management vs Regulatory

The National Forest Management Act provides adequate authority and direction to achieve healthy riparian conditions to the extent that Forest Plans recognize the issue and set and implement appropriate standards. Regulatory programs such as the dredge and fill provision of Section 404 of the Clean Water Act while important provide only a supplemental reason for management action.

Area vs Zone

The terms riparian ecosystems or riparian areas should be used more precisely. The term "Riparian Area" describes a unit of land associated with perennial surface water that contains a wetland or riparian ecosystem plus the one-hundred foot special consideration area and the aquatic ecosystem. The term "zone" should be reserved for situations where specific regulatory prohibitions on use are applied to a portion of a Riparian Area.

Results vs Promises

Perhaps the most important aspect of the strategy revolves around delivery of positive on-the-ground changes in riparian management. Forest Service promises to improve riparian areas must be supported by visible on-the-ground improvement. The problem solution must provide for a sustainable and healthy riparian conditions that support all riparian resources.

CHIEF'S RIPARIAN GOALS

Chief F. Dale Robertson (1992) outlined the following six goals in a message to line officers in 1992:

1. Improve 75 percent of unsatisfactory riparian conditions to meet forest plan standards by the year 2000; improve the remaining unsatisfactory areas by 2010.
2. Design activities and conduct current uses so that healthy riparian areas and wetlands will not be degraded by human activities.
3. Strengthen regional guidance and incorporate additional standards and direction in forest plans, as necessary, to sustain the health of riparian areas that are affected by mining, recreation, wildlife and domestic livestock, off-road vehicles, roads, and other activities.
4. Assist and advise landowners, through cooperation with State Foresters and the Soil Conservation Service, to identify and manage riparian areas and to improve and sustain riparian productivity.
5. Continue active riparian and woodland research.
6. Begin riparian demonstration projects on all ranger districts by fiscal year 1992.

In addition, the Chief called upon line officers to adjust activities and uses affecting Riparian Areas to achieve consistency with existing forest plan standards and guidelines.

SUMMARY

Riparian Areas form the vital link between watersheds and stream systems. They act as flood dissipators, nutrient scrubbers, sediment filters, temperature controllers, stream bank stabilizers, conduits for exchange with groundwater systems, water storers and regulators, sources of organic structures, habitat for terrestrial, amphibian, avian, and aquatic animals, corridors and connectors with other ecosystems, and recreation venues. Performance of these functions depends on having a riparian ecosystem in optimum health.

Healthy implies that the system is resilient and that the seral state lies within a sustainable riparian continuum and does not represent a shift toward upland conditions. Optimum health implies a system that provides for a maximum diversity and quantity of benefits giving preference to those benefits that depend entirely on riparian ecosystems. We need to maintain the current level of concern and increase our level of action to obtain the desired future conditions outlined for riparian areas in the Forest Plans. Sustaining favorable conditions of streamflow from the National Forest depends in vital part on attaining and sustaining healthy riparian ecosystem conditions.

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Riparian Area Enhancement Through Road Design and Maintenance

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Abstract.—Traditional road location, design, construction, and maintenance have generally had adverse effects on riparian areas. Road locations, drainage methods, and maintenance practices have resulted in a net loss of both acreage and related values in riparian areas, particularly in the arid and semi-arid portions of the West. Results of these activities include drainage of riparian ecosystems, reduced site productivity, loss of fish and wildlife habitat, reduced base flows with increased peak flows, gully development, and accelerated downstream sedimentation. Recent changes in management philosophy and activities are reversing this trend by using road design and maintenance to rehabilitate riparian areas and restore their productivity. Methods being used to accomplish these goals include road obliteration, road relocation, modified culvert designs, raised culvert inlets, modified bridge and ford designs, flow dispersal, stilling basins, and more frequent and effective ditch management. Results have been dramatic, with nearly 100 acres (405 hectares) of degraded riparian area in the USDA Forest Service Southwestern Region started on the road to recovery over the past five years. Transportation system management is becoming an effective tool in the rehabilitation of riparian areas across the Southwestern Region.

INTRODUCTION

The Southwestern Region of the USDA Forest Service encompasses roughly 22.5 million acres (9.1 million hectares) in 11 National Forests and Grasslands on 64 Ranger Districts across Arizona, New Mexico, and western Oklahoma and Texas. Riparian areas and related wetlands occupy approximately 1 percent of this area, but they receive a disproportionate amount of use in relation to their size. Due to limited water in the arid and semi-arid Southwest, riparian areas have become the focal point of activities since their attributes include water, shade, productive soils, gentle topography, and many related values.

For many historical and topographic reasons, roads have often seen located adjacent to water bodies and cross them frequently. Traditional road location, design, construction, and maintenance activities have had considerable negative impact on riparian areas across the Southwest. Many of these impacts were unintentional and simply followed long-held engineering training and practice. Modern managers have begun to realize the extent and magnitude of these impacts on riparian areas and their related values. Successful efforts are underway to prevent further losses and restore many areas to productivity.

This paper has several main objectives: (1) present a historical perspective on road-related impacts on riparian areas in the Southwest; (2) discuss how these impacts were recognized and analyzed; (3) list typical problems associated with road/riparian conflicts; (4) present suggested solutions, and methods to avoid

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future problems or correct existing ones; and (5) discuss program progress to date and likely future accomplishments.

Accomplishing changes in road management to benefit riparian area resources requires those involved to be open to new and emerging approaches to road and water management (Figure 1). Traditional approaches to design, philosophy, and policy worked to collect, concentrate and discharge water. Water was viewed as a liability. Designs were single purpose, with an uncompromising and indifferent view toward related resource values.

Newer thinking views water as an asset. Designs are multi-purpose and multi-valued. Water is detained on site. Flow is dispersed and spread through the area in natural patterns where it can benefit a wide range of resources and users.

DEFINITIONS

The Forest Service Manual section FSM 2526.05 (USDA, 1986, 1991) defines riparian areas, including wetlands, as we use these terms throughout this paper. Riparian Areas are comprised of two ecosystems: riparian and aquatic. The Aquatic Ecosystem includes the stream channel, lake, or estuary bed; water; biotic communities; and the habitat features that occur therein. The Riparian Ecosystem is comprised of terrestrial ecosystems characterized by hydric soils and plant species dependent on the water table (saturated zone) and/or its capillary fringe.

Wet Meadows are meadows having low velocity surface and subsurface flows. Channels are typically poorly defined or nonexistent. Vegetation is dominated by riparian-dependant species. Xeric species are confined to adjacent uplands or drier inclusions within the meadow.

Design Approaches

Old/Traditional	New/Emerging
Collect Water	Control/Manage Base Level
Concentrate Flow	Disperse/Spread Flow
Direct Flow	Detain Water On Site
Drain/Discharge Water	Slow Flow
Accelerate Flow	

Philosophical/Policy Approaches

Old/Traditional	New/Emerging
Water Viewed As Liability	Water Viewed As Asset
Single Purpose Oriented	Multi-purpose Oriented
Uncompromising	Compromising
Narrow Scope	Broad Scope
Indifferent	Nuturing/Concerned

Figure 1. Approaches to road/water management.

HISTORICAL PERSPECTIVE

Water has long been a limited resource in the arid and semi-arid West. Riparian areas have always comprised a small portion of the Southwestern landscape. Even prior to the arrival of European immigrants, riparian areas probably involved less than 2 percent of the total land area. Recent reports indicate that, on a statewide basis, approximately 50 percent of the original acreage of riparian areas (including wetlands) in the Southwest have been lost or significantly degraded (U.S. GAO, 1988; Dahl, 1990, p. 6). Human activities have caused changes in watershed condition, hydrologic function, and soil productivity, which subsequently increased runoff, erosion, and sedimentation. These activities include but are not limited to: timber harvest; domestic livestock grazing; placer mining; water management activities such as diversions, dams, flood control, irrigation, drainage of wetlands, channelization, phreatophyte control; and road construction and maintenance.

Road construction and maintenance have been major contributors to riparian area losses over the years. Reasons for this are rooted in historical patterns of travel and commerce in the West. Old wagon routes tended to follow stream corridors since they usually offered many advantages over other routes. Stream bottoms had more gentle terrain, offered water and forage for horses and other livestock, housed fish and game for food supplies, and provided wood for fires and building materials.

Early roads and highways followed these old established routes along stream bottoms, where construction was usually easier and less expensive. Drainage and maintenance practices were designed to move water away from the road to keep the road surface and subsurface dry. Infrequent large drainage structures, augmented with extensive ditch net-

works, were preferred over numerous small structures to save effort and expense. Maintenance practices commonly routed water and sediments from the road surface and ditches directly into stream courses for rapid removal. This benefitted the road, but commonly caused unintentional harm to other resources by fostering extensive gully development and erosion of riparian areas.

Western water laws of prior appropriation required that water be diverted from the stream and put to a "beneficial" use. Until recently, water left in the stream was not considered "beneficial" in most western states. Little concern existed for fish passage or wildlife habitat. Water quality was not important in dry streams. Road-related recreation use along roads near streams further disturbed banks and riparian areas.

Over several centuries of habitation by European immigrants, riparian areas in poor condition and dewatered meadows with deep gullies became a common sight. Most people then and today have come to accept these conditions as "normal" and have no vision of what the land can and should look like. Until recently, little thought had been given or action taken to correct the situation.

PROBLEM RECOGNITION

Recognizing and becoming aware of a problem requires a willingness to see an existing situation from a different perspective. This calls for an open mind and a change in attitude and philosophy about the situation. Eventually, observant and concerned professionals began to notice the nature and magnitude of riparian area losses related to road construction and maintenance. These effects include: (1) riparian areas de-watered due to lowered channel bed nick points and gully formation and advance; (2) plant composition changed, with a shift from riparian dependant plants to drier and less productive upland species; (3) accelerated runoff caused increased flood peaks and related damages; (4) base flows decreased in volume and duration, causing streams to dry up earlier in the year; (5) perennial streams reduced to non-perennial flow; (6) increased channel bed and bank erosion; (7) eroded soil increased downstream sedimentation; (8) reduced habitat for riparian dependant wildlife species; (9) rapid movement of water off the land to water storage facilities at lower and hotter elevations increased water losses through higher evaporation rates; (10) improper road drainage led to higher road maintenance costs; (11) compromised safety of forest users from abnormal flooding; and (12) Forest facilities endangered by higher flood frequencies and magnitudes (DeBano and Schmidt 1989).

These effects were recognized first by professionals who's programs were most directly effected by riparian area losses: wildlife and watershed managers. Spurred by the concerns of these individuals, several on-the-ground managers began to experiment with different ways to improve road management in riparian areas. Their work provided good examples for others to observe, evaluate, and emulate. The staff of the Apache-Sitgreaves, Cibola, Gila, and Prescott National Forests (NF) took the lead in this arena and continue to lead the agency in developing these innovative road management practices.

The Regional Office staff is working to with the Forests to reduce the impact of roads on riparian areas. Together they are developing and implementing programs to reduce the impacts of current and future roads as well as actively use road management as a tool to rehabilitate areas damaged by past actions. This knowledge is beginning to spread to other Regions and agencies across the country.

PROBLEM ANALYSIS

Within the Southwestern Region the Forest Service manages approximately 53,000 miles (85,277 kilometers) of roads. The Region constructs an average of 60 to 70 miles (96.5 to 112.6 kilometers) of new road each year and reconstructs another 350 to 400 miles (563.1 to 643.6 kilometers). At the same time, nearly 1,000 miles (1,609 kilometers) are temporarily closed or permanently obliterated annually. This level of activity presents many opportunities to remedy riparian losses caused by previous road management activities.

In an effort to learn which methods worked best in different situations, several fact-finding visits were made to the lead Forests during 1989, 1990 and 1991. A team comprised of Directors and specialists from Watershed and Air Management, Wildlife and Fisheries Management, Engineering, and Range Management visited a wide variety of sites on these Forests. Similar trips were then made to other Forests to observe current practices and encourage the use and acceptance of successful modern road management methods. These trips consisted of a brief in-office presentation of concerns and ideas, followed

by visits to an array of suitable field sites, and a close-out meeting to discuss observations and opportunities for future work. The response on these trips was highly positive and encouraging, and many excellent ideas emerged.

Several basic categories of problems were observed and analyzed. These included: (1) wet meadow crossings and adjacent road locations; (2) routine stream crossings, including culverts, fords, and bridges; (3) road alignment on the landscape; and (4) road drainage, such as ditches, dips, and water bars. The team summarized and described findings, and developed a series of slides and line drawings to illustrate typical areas of concern, successful remedial methods, and ways to recognize opportunities for employing these techniques.

Problem Statements and Solution Proposals

The observational information collected during the Region-wide analysis of road design and location was used to develop problem statements and solutions for a variety of field situations. These situations include: roads and wet meadows, stream crossings (e.g. culverts, low water crossings, and bridges), road location and alignment, and road drainage. Also, many recommendations developed were based on information presented by Heede (1980) and DeBano and Schmidt (1989).

Roads and Wet Meadows

Problem Statement

In their natural condition, wet meadows typically have dispersed surface and subsurface flows at low velocities. The resulting areas are characterized by riparian obligate species present in the meadows with the more xeric species, which cannot tolerate wet conditions, confined to drier upland slopes or inclusions. Roads often violate this natural landscape feature by crossing the wet meadows or closely paralleling them (Figure 2). As a result, a road and its drainage structures tend to cut off dispersed water flow into the meadow, or concentrate flows and increase velocities through specific structures. Drainage structures are commonly excavated to set on "mineral" soil, which is below the natural grade of the meadow. This results in gully formation above and below the road. The concentrated flows cause channel downcutting, and gully erosion inevitably follows. The gullying gradually dries out the meadow as the channel deepens. The loss of a permanent water table by gullying leads to the encroachment of upland plant species into the formerly wet meadow, changing the vegetation composition, diversity, and productivity.

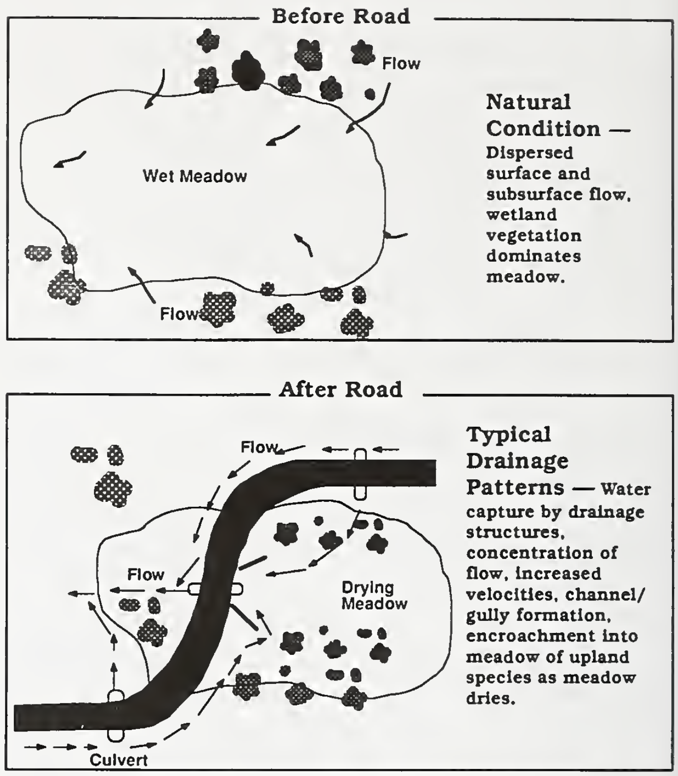
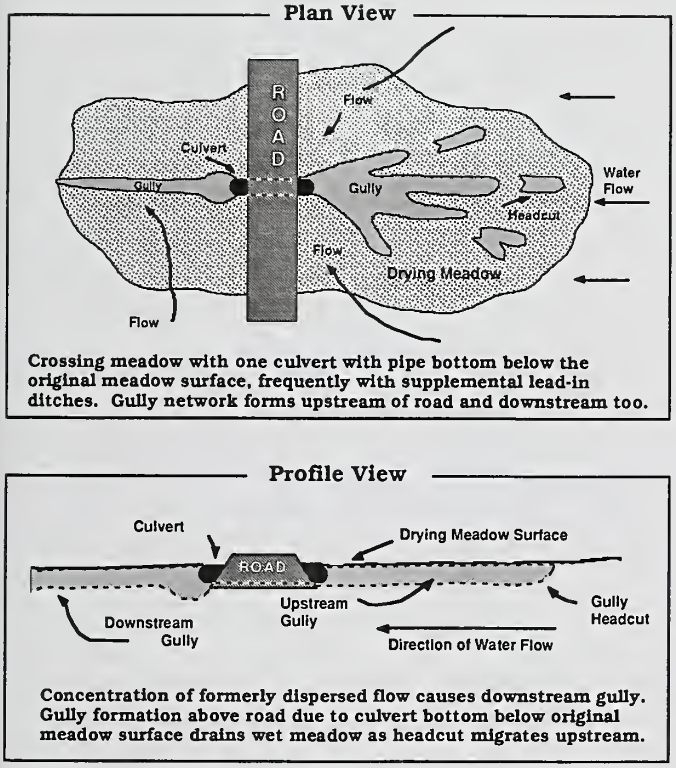


Figure 2. Typical water management scenario for roads and wet meadows.

Solutions

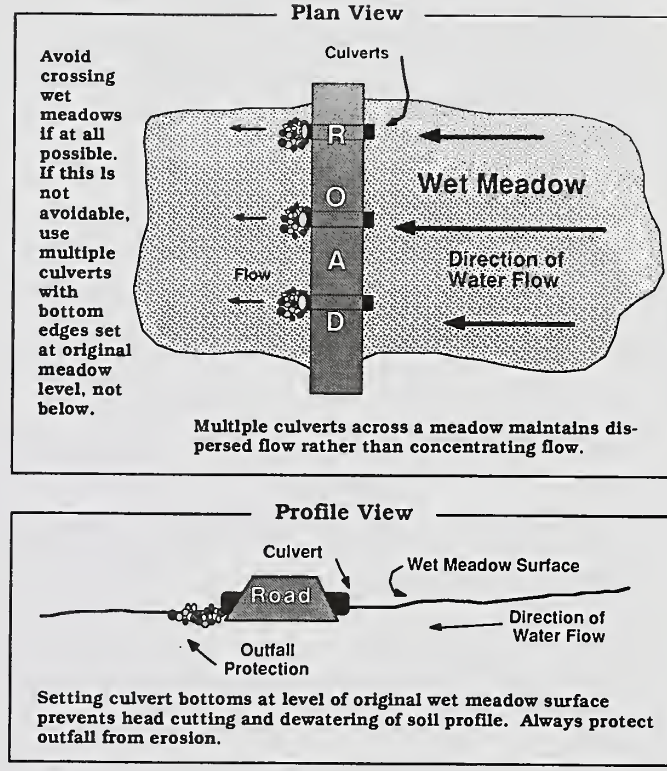
The best solution to the adverse effect of roads on wet meadows is to avoid crossing them altogether. Select alternative routes at higher elevations that minimize the effects of road construction on the meadow. When it is not possible to avoid crossing the meadow, use construction methods that have minimal impact on the area (Figures 3-4). Preferable locations are to cross either below (Figures 5-6) or above (Figures 7-8) the meadow. Also, whenever possible, take advantage of local geologic features by crossing at natural pinch points, at grade, and at right angles to the flow direction in order to minimize impacts.



Crossing meadow with one culvert with pipe bottom below the original meadow surface, frequently with supplemental lead-in ditches. Gully network forms upstream of road and downstream too.

Concentration of formerly dispersed flow causes downstream gully. Gully formation above road due to culvert bottom below original meadow surface drains wet meadow as headcut migrates upstream.

Figure 3. Road crossing through a wet meadow — improper method.



Avoid crossing wet meadows if at all possible. If this is not avoidable, use multiple culverts with bottom edges set at original meadow level, not below.

Multiple culverts across a meadow maintains dispersed flow rather than concentrating flow.

Setting culvert bottoms at level of original wet meadow surface prevents head cutting and dewatering of soil profile. Always protect outfall from erosion.

Figure 4. Road crossing through a wet meadow — proper method.

Stream Crossings

Problem Statement

The most common forms of stream crossings are culverts, low water crossings, and bridges. Some problems are common to all, while others are specific to the type of stream crossing.

Several mistakes are commonly made when installing culverts. First, when installing culverts, a few large culverts have usually been preferred to numerous small ones because the installation effort and costs are less for fewer large culverts. This presents a problem since directing all the flow through one opening concentrates energy, increases velocities, and accelerates erosion upstream and downstream of the crossing. Also, culverts are commonly placed with the culvert bottom excavated down to mineral soil, usually below the natural grade of the stream bottom. This practice keeps the road prism dry and provides excellent bedding for the pipe, but can lead to both upstream and downstream channel degradation. The culvert outfall is commonly unprotected and creates a scour hole, which lowers the channel and results in drying of the surrounding riparian areas. In the upstream direction, side channel downcutting may occur and initiate upstream gully systems. Also, the sediment lost by both upstream and downstream erosion can affect downstream water quality. In addition, culverts that are too long, too steep, or having outfalls too high may impede fish passage.

Low water crossings (fords), when set below the natural grade, can also cause channel degradation both upstream and downstream from the structure. Failure to include a cutoff wall and splash apron in

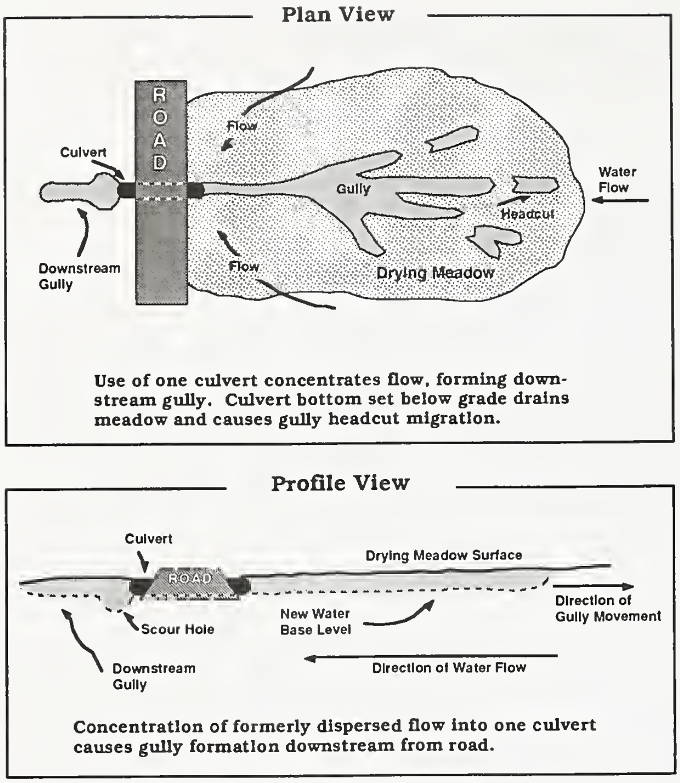


Figure 5. Road crossing through a wet meadow — improper method.

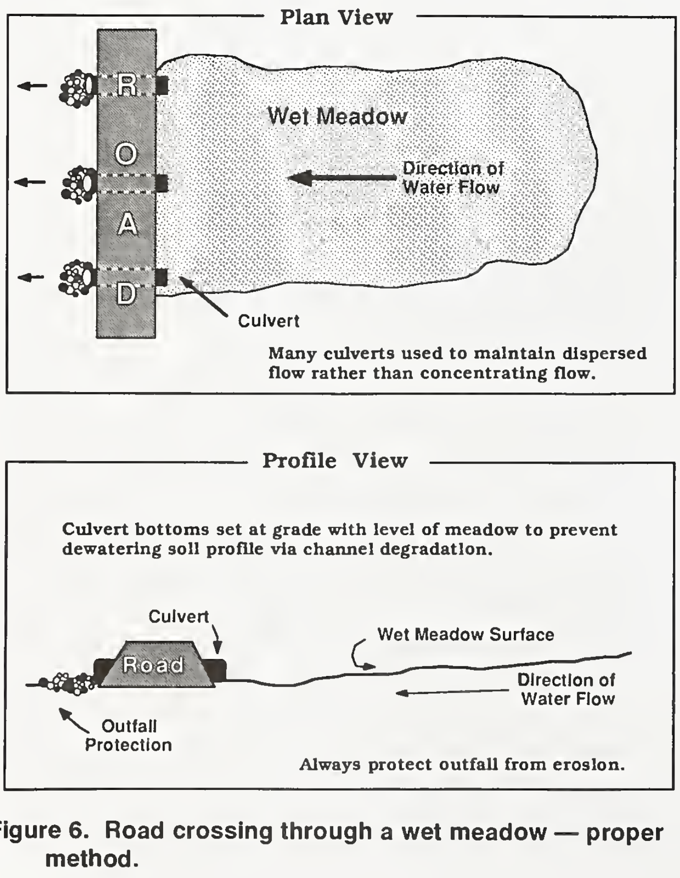


Figure 6. Road crossing through a wet meadow — proper method.

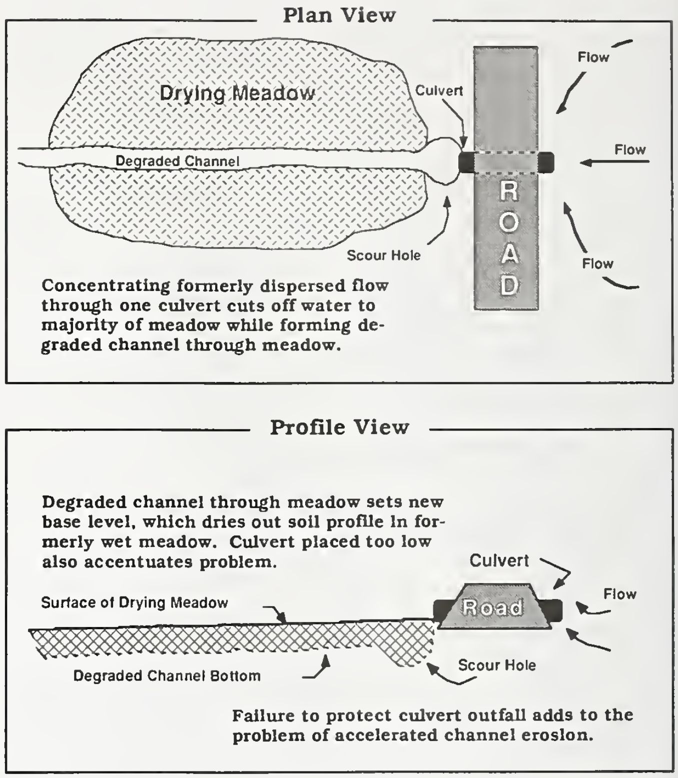


Figure 7. Road crossing through a wet meadow — improper method.

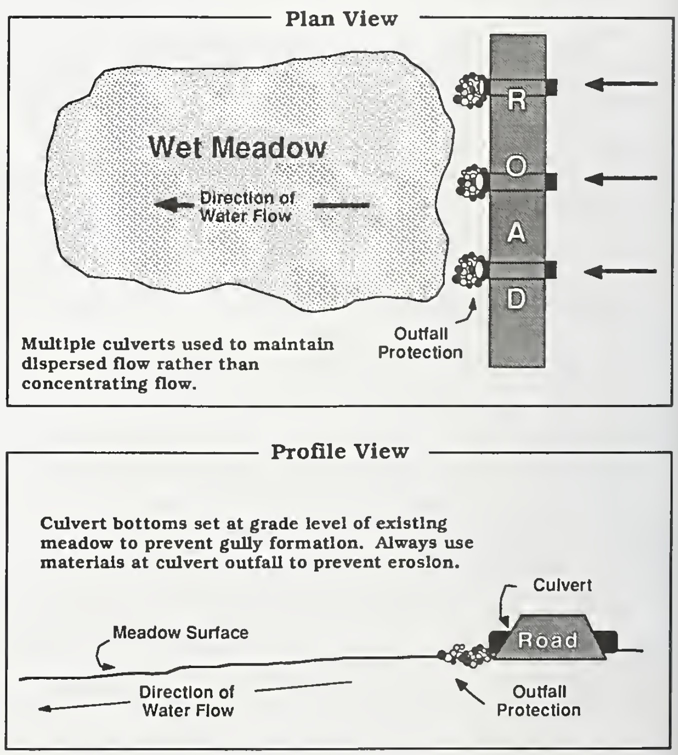


Figure 8. Road crossing through a wet meadow — proper method.

the design commonly results in formation of a scour hole and eddies below the structure. This undermines the crossing, resulting in high maintenance and eventual failure of the crossing.

Two common mistakes occur when constructing bridges. First, the opening is made too small to pass design flows. This reduces flow velocities above the bridge, which results in upstream aggradation. Also, the water passing though the structure accelerates, causing degradation of reaches below the bridge. The second common problem associated with bridges involves construction at an angle to the natural flow of the stream. This forces the water to impact the bank above the bridge and exit at an angle below it. A related problem is caused by channelizing the stream to align it with the bridge rather than aligning the bridge with the stream. Undersized openings and improper alignment endanger the structure and the riparian areas near it. The eroded soil generated as a result to improper alignment can also affect downstream water quality.

Solutions

Mitigating the effects of different kinds of stream crossings share some solutions. Others are unique to each structure type.

The number, location, alignment, and elevation of inlets are important considerations when installing culverts for road crossing. When the streamflow is not naturally concentrated into a single channel, as in a meadow, cienaga, or braided or wide channel, use multiple smaller culverts placed over the width of the affected area to spread the flow energy rather than using one large culvert that concentrates flow. Elevation of inlets are important when installing culverts. Where new construction or reconstruction allows choice in location of culverts, place the bottom of the culvert at the natural level of the channel. If proper bedding is a problem, excavate and refill to the natural level of the channel. Where previous channel degradation has occurred and restoration of the natural channel is the goal, place the culvert at the bottom at the desired channel elevation. This will allow sediments to aggrade the bed back to the original level (Figure 9). This may require more fill but the benefits to riparian resources will justify the additional cost.

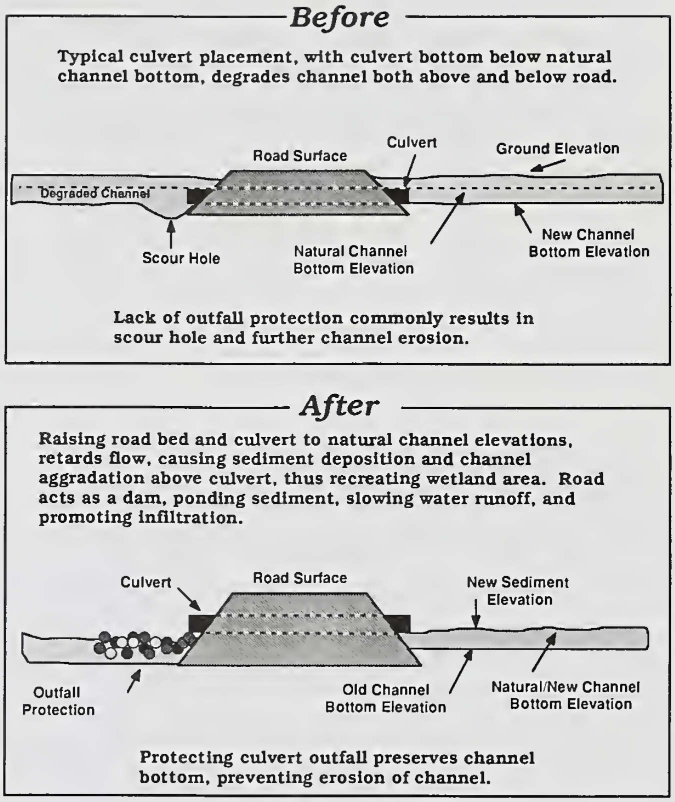


Figure 9. Raising culvert elevation to recreate wet area.

Where existing culverts cannot be changed, and aggradation of the channel is desired, construct an upstream dike to raise the water/sediment level and then drop the water safely to the existing culvert level. Construct upstream dikes of soil, rock, metal, concrete, wood or other suitable materials (Figures 10-11). Use caution in design to assure the new water/sediment elevation is less than the road surface elevation.

Another technique for raising the upstream end of a culvert involves attaching a 45 - 90 degree elbow with the elbow inlet at the desired stream bottom level (Figure 11). Provide sufficient freeboard on the fill to avoid overtopping the road. Culvert elbows also change the characteristics of how water enters the culvert, reducing its capacity under high flow conditions.

Align culverts with stream direction and gradient to assure that sediment passes through the culvert rather than accumulating inside it. When fish passage is necessary, make sure culvert openings will allow passage, especially at outfalls.

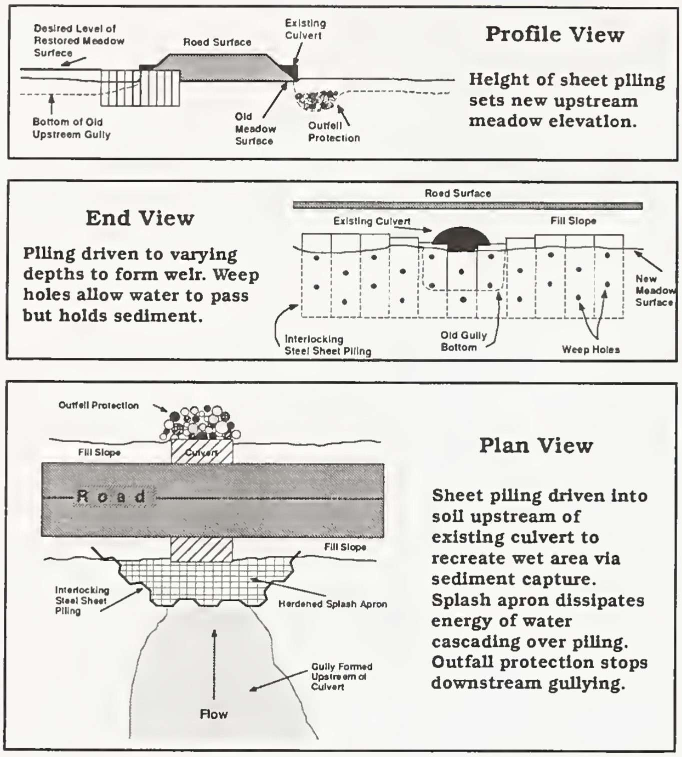


Figure 10. Using interlocking steel sheet piling upstream of an existing culvert to recreate wet area.

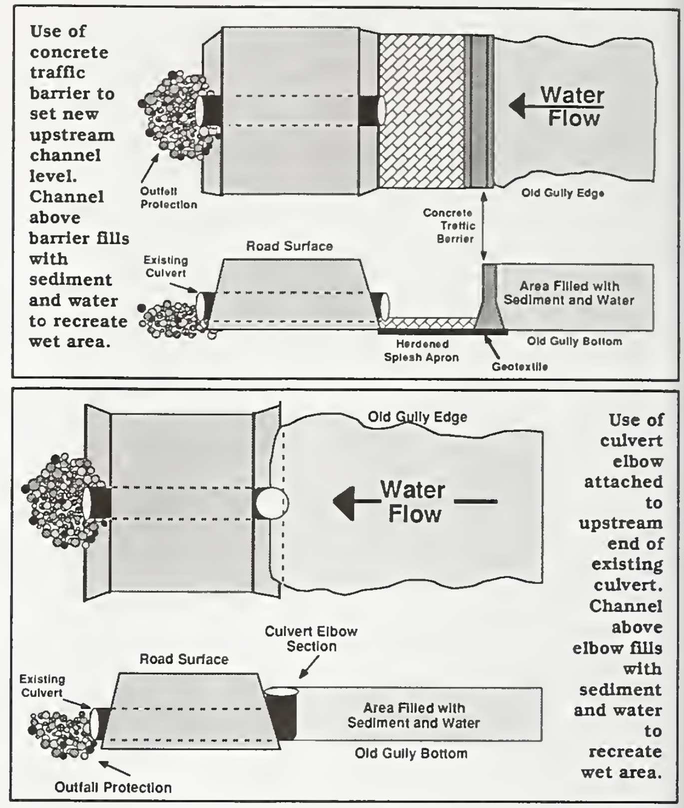


Figure 11. Modifying culvert inlet to recreate wet area.

Special considerations when constructing low water crossings include maintaining the natural grade, installation of cut-off walls, providing sufficient channel capacity, and using "French" drains. The construction of "French" drains, which is rock sandwiched between layers of geotextile (Figure 12), allows water to pass through the road prism and at the same time keeps the road surface dry. They may be used alone or in conjunction with a culvert or dip designed to pass large runoff events.

Place crossing surfaces at the grade of the natural channel to maintain the current channel or facilitate aggradation of a degraded channel. The low water crossing should extend far enough up the stream banks to keep high flow events from eroding the ends of the structure. Install a cut-off wall at the downstream edge of the road surface to prevent undermining the structure. Construct a splash apron at natural channel gradients downstream of the cut-off wall to dissipate flow energies passing over the structure, thus avoiding erosion and eddies that could undermine the crossing (Figure 13).

Two important considerations when using bridges include flow capacity and an alignment with the stream channel. Construct the bridge opening sufficiently large to pass expected volumes without constricting flow. Avoid the temptation to construct a smaller opening to save initial costs. Future maintenance costs and damage to other resources may outweigh the higher initial cost of construction. The construction of secondary relief structures, such as dips or "sacrifice" bridge approaches are recommended. Build the bridge at right angles to flow. Avoid building bridges on curved stream reaches when possible.

Road Location and Alignment

Problem Statement

Many roads in the Southwest tend to closely follow and frequently cross streams and riparian areas because of the historical reasons discussed ear-

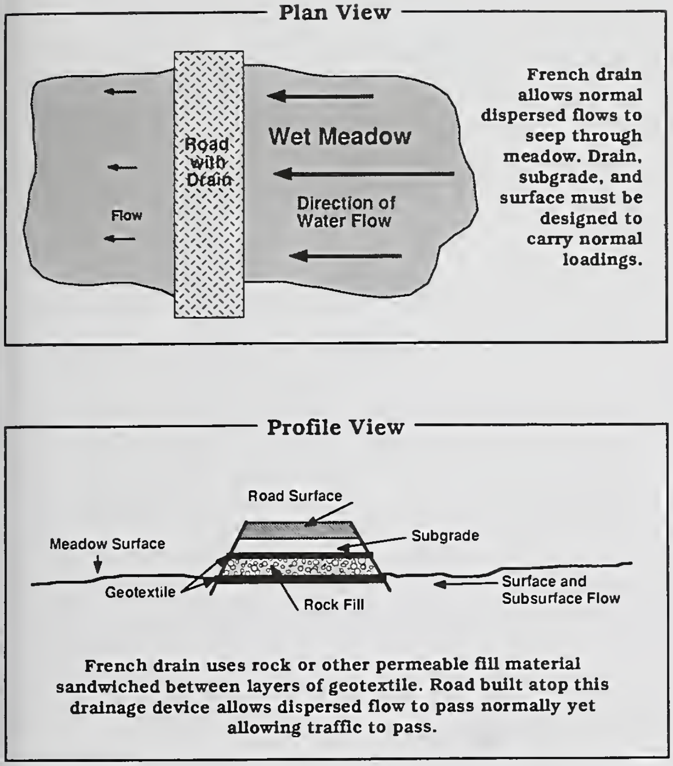


Figure 12. Use of french drain to cross wet area.

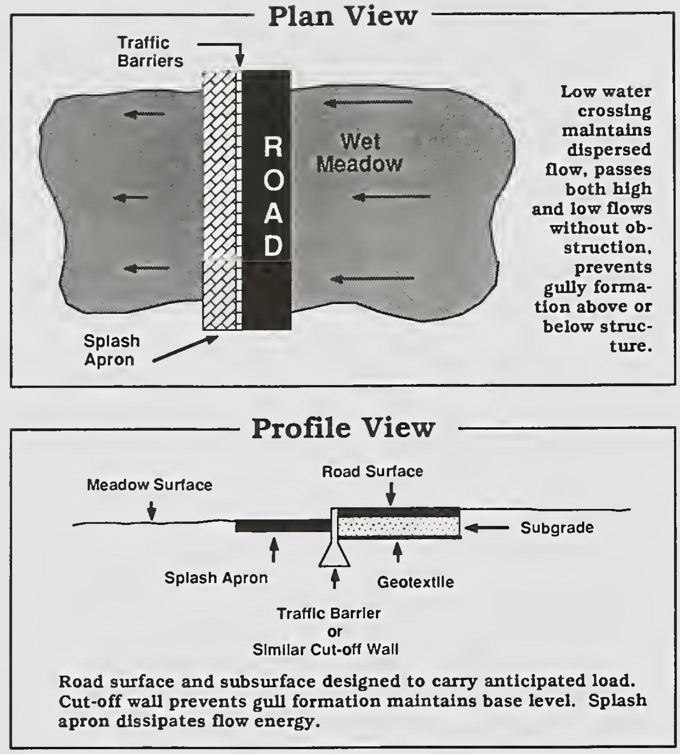


Figure 13. Use of low water crossing (fort) across wet area.

lier. Roads in riparian areas can take up a significant portion of the total area, replacing natural vegetation with an impermeable surface. This increases runoff and flood peaks while passing sediment and other pollutants into the stream. Locations often cut off or shorten stream meanders. This steepens channel gradient, increases stream power, and causes erosion and downstream sedimentation. Roads cut through alluvial fans may intercept and concentrate surface and subsurface runoff, with adverse effects downstream from the road.

Solutions

Keep roads completely out of the riparian areas whenever possible. Build roads on the ridges or sideslopes. While initial construction costs may be higher, long-term maintenance costs will be less and reduce damage to riparian resources. Minimize the number of crossings where they cannot be eliminated. Limiting crossing reduces potential problems and long-term expenses. Design and construct roads to detain or delay water and sediment upstream from the road. This reduces flow velocity, increases infiltration, and prolongs base flows below the road. Do not cut off or shorten stream meanders with crossings or road fill materials. Naturally occurring meanders are necessary to maintain an equilibrium gradient with the stream. Avoid building roads through alluvial fans. Provide drainage to mimic natural patterns where avoidance is impossible.

Road Drainage

Problem Statement

Drainage of water from roads, especially from ditch lines, can impact nearby riparian areas. Infrequent drainage allows water to travel for long distances in ditches, gaining velocity and sediment loads while reducing flow to meadows. Drainage outlets too close to channels can direct pollutant-laden water directly into the stream. Wing ditches and berms along roads frequently disrupt natural flow lines and concentrate flow where it causes erosion. Drainage outlets on fill materials commonly cause significant erosion. Unprotected culvert outlets cause scour and

additional sedimentation. Too frequent maintenance can remove erosion-resistent vegetation or rock armor, undermine stable banks, and increase erosion and sedimentation.

Solution

Where possible, use outsloped roads and rolling dips to avoid inside ditches. When ditch construction is limited to insloped roads, drain the water from the road frequently, avoiding flow concentrations in the ditch and at any single culvert. Protect drainage outlets against erosion by placing the outlet at the gradient of the channel bottom and installing energy dissipators at the outfall. Avoid placing outlets on fill material. Avoid directing accumulated ditch waters and sediment into streams. Turn ditch waters onto areas that will allow the water to infiltrate and sediment to settle out before reaching the stream. Construct stilling basins if necessary to provide these results. Maintain ditches and road surfaces at the minimum necessary to get the job done. Don't "over maintain" a road or "pull" ditches if they don't need it. Vegetation in the ditch can prove beneficial by stabilizing the ditch and cut slope, preventing erosion of both.

Program Advantages and Benefits

Managing roads with riparian area values in mind can yield a wide range of multiple benefits. Benefits include but are not limited to: (1) rewetting dewatered wetlands and re-creating former riparian areas; (2) limiting or reversing reductions in riparian acreage, resulting in an actual net increase in riparian areas in many instances as historic riparian areas are rehabilitated; (3) reducing flood peaks and related damages; (4) increasing base flow volume and duration; (5) limiting or stopping channel erosion and downstream sedimentation; (6) creating riparian areas using sediments trapped from uplands; (7) lengthening streamflow duration, sometimes returning once-perennial streams to perennial flow; (8) reducing water loss from evaporation in downstream reservoirs by storing it in the upstream soil profile; (9) increasing wildlife and fisheries habitat quality, quantity, and diversity; (10) increasing forage production for livestock and wildlife; (11) increasing recreation benefits and aesthetic values; (12) reducing road maintenance costs; (13) turning water, which was formerly perceived as a liability, into an asset; and (14) complying with Executive Orders 11988 and 11990 on management of floodplains and wetlands.

Program Implementation and Progress

Many techniques are available to implement these new and revised ideas into everyday management, including: (1) design new roads using the concepts presented above; (2) reconstruct old roads using these concepts; (3) retrofit other roads during periodic maintenance, where appropriate and as opportunities allow; (4) use multiple funding from all benefiting resources; (5) train current and new employees to use these ideas through workshops, handbooks, videos, photo libraries, and related methods; (6) provide training to increase awareness of engineering personnel to other resource skills and needs; and (7) cross-train resource specialists to appreciate engineering skills and needs.

Progress to date is very encouraging. A wide variety of measures have improved nearly 1,000 acres (404.7 hectares) of riparian area across the Southwestern Region over the past several years. Particular success has occurred on the Luna and Reserve Ranger Districts of the Gila NF, Alpine and Springerville Ranger Districts of the Apache-Sitgreaves NF, and Mt. Taylor Ranger District of the Cibola NF. Some of the most notable examples are found on the Alpine, Luna, and Mt. Taylor Ranger Districts.

Planned reconstruction of nearly 60 miles (96.54 kilometers) of Forest Roads 49 and 50 in the Zuni Mountain section of the Mt. Taylor District near Grants, NM, will provide a showcase for demonstrating methods to protect and enhance riparian areas using modern road management concepts. Initial survey and design efforts show that an estimated 2,000 acres (809.4 hectares) of riparian area can be rehabilitated using a wide variety of proven and evolving technologies. Scientists from the Rocky Mountain Forest and Range Experiment Station are working with the project designers to establish research studies for evaluating changes in areas affected by the new road project. Expected changes include: extent and depth of water tables; soil moisture and productivity; water yield and timing, vegetation density, composition, and yield; sediment deposition; and wildlife use.

The added cost incurred from incorporating these riparian management concepts in the construction, reconstruction, and maintenance of roads is usually marginal. Retrofitting existing structures can be accomplished using simple materials and District and/ or volunteer labor in many instances. One prime example on the Apache-Sitgreaves NF involves raising the inlet of a culvert by building an upstream structure using railroad ties, rock, and grout. Installation was done by volunteers over a weekend. The structure is capturing sediment and slowing runoff on an estimated 70 acres (28.3 hectares) of riparian area. Since the total cost of materials for the project was only $700, costs for the work were a minimal $10/ acre ($25 per hectare)! Other similar examples demonstrate that effective structures need not be large or expensive. Small, well-implemented designs are often less labor-intensive and require less future maintenance than large, elaborate measures.

SUMMARY AND CONCLUSION

For many reasons over many years, road location, design, construction, and maintenance have commonly proven detrimental to riparian areas and related resources, reducing acreages and multiple values. We now realize that many opportunities exist to regain lost acreages and values. Since many recommended techniques are relatively small and simple, costs for most design adjustments are inexpensive. Accumulated multiple benefits derived in most cases easily outweigh any additional costs. Technology to accomplish these goals already exists and continues to evolve today. Little research and development is needed to implement many of these practices; however, some research will be helpful in defining rates and kinds of benefits derived. Awareness and enthusiasm provide the keys to success in managing our road systems to enhance riparian areas and related benefits.

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Understanding and Managing Southwestern Riparian-Stream Ecosystems: National Forest Systems and Forest Service Research Partnerships

Leonard F. DeBano[1,4], John N. Rinne[2,4], and Alvin L. Medina[3,4]

Abstract.--Partnerships between research scientists and land managers can facilitate the application of research findings. Successful partnerships developed between Rocky Mountain Station scientists and the Southwestern Region staff have been involved in addressing riparian-stream interactions. These successful partnerships involve several interpersonal and organizational considerations. Examples and Keys to successful partnerships are described.

INTRODUCTION

Although National Forests cover over 21 million acres in Arizona and New Mexico, less than 1 percent is comprised of riparian ecosystems (Rinne and LaFayette 1991). Riparian areas in the semi-arid regions, such as the Southwest, are extremely valuable for wildlife and fish habitat, recreation, maintaining landscape diversity, sediment filtering and flood reduction, points of recharge for ground water, maintenance of water quality, commercial timber, and sustainable forage for livestock and wildlife (DeBano and Schmidt 1989).

Since the late 1800's, the impact of extensive unmanaged livestock grazing, wildfires, and forest clearing--coupled with numerous small linear perturbations such as travelways, low standard roads, and livestock trails--have dramatically influenced the land-riparian interactions observed today. Vegetation removal and soil compaction have substantially increased surface runoff, produced sediment-laden flows, and increased erosive power to the channel system, which has upset the balance between riparian areas and the surrounding watershed (LaFayette and DeBano 1990), leading to the degradation, channel incision, and (in some cases) complete destruction of riparian areas. Estimates of the total loss of southwestern riparian areas vary widely. The greatest losses have occurred along the banks of the larger river systems flowing through the lower elevation deserts, where up to 90 percent of the area has been lost (Carothers 1977). Higher elevations have fared better. But the overall loss of riparian areas for the state of Arizona has been estimated to be 30 to 35 percent (Dahl 1990).

Past information about riparian areas and their relationship to the surrounding watersheds is fragmented and dispersed through the literature. Only recently has some of this information been synthesized into state-of-the-art and other technical publications that link these research findings to management applications. The development of these publications has been prompted by establishing partnerships between key Rocky Mountain Station (RMS) scientists and Southwestern Region (R-3) managers, National Forest System (NFS).

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The objectives of this paper are to: (1) present a brief overview of three examples of successful partnerships between NFS and RMS involving southwestern riparian areas, (2) identify some specific products generated by these partnerships, and (3) summarize some of the requirements for establishing successful research-management partnerships. Readers who are interested in further detail of the brief overviews presented in this paper are encouraged to obtain and study copies of the individual publications. The following syntheses of published and unpublished work have helped NFS managers conceptualize research information:

SUCCESSFUL PARTNERSHIPS AND PRODUCTS

Partnership I - Publication on Riparian Area Enhancement

Although considerable effort has been concentrated on vegetation structure and classification, plant succession, water consumption, and grazing-wildlife interactions in riparian areas, only recently have the beneficial effects of different watershed practices on enhancing riparian areas been recognized. In the past, several watershed rehabilitation treatments were implemented solely for erosion control without realizing the additional benefit these treatments could have on improving and enhancing riparian areas.

To document these benefits, DeBano and Schmidt (1989) prepared a state-of-the-art report on riparian hydrology in the Southwest that summarized and interpreted data collected during past studies in the Southwest and throughout the West. Their paper provided general guidelines for improving hydrologic relationships in naturally occurring and human-induced riparian areas. The authors highlighted the effects that different watershed treatments have on enhancing riparian areas. This publication assumed that opportunities for riparian enhancement should be considered while improving watershed condition and riparian health.

Management opportunities for rehabilitating many upland riparian areas generally involve improving watershed condition, modifying plant cover by replacing deep-rooted shrubs with shallow-rooted grasses, installing small channel structures or gully plugs, or using a combination of all these rehabilitation techniques. Implementing these practices can alter both the amount and duration of streamflow. Before implementing watershed treatments, however, land managers need to be aware of the strong relationship between watershed condition and riparian health so they are better able to assess treatment effects. In nearly all cases this requires an interdisciplinary approach to management, covering abiotic as well as biotic factors operating within a watershed.

Products.--The most important products for NFS managers resulting from the synthesis by DeBano and Schmidt (1989) were: (1) a reference source of past watershed rehabilitation treatments, (2) a synthesis of existing information on watershed practices that is useful for both watershed and riparian rehabilitation, (3) guidelines for improving watershed condition and riparian health, and (4) identification of further research needed for southwestern riparian areas.

The publication also discusses the health of riparian areas, where a healthy riparian area reflects a dynamic equilibrium (i.e., volumes of incoming sediment equal those of outgoing sediment). In this condition, riparian vegetation remains vigorous but does not encroach into the active mean annual flood channel. In addition, streamflow does not rapidly expand stream meander cutting or point bar growth through the riparian area or affect it by eroding the channel bed. This equilibrium between channel deposition and down-cutting by erosion in riparian areas was illustrated by using a simple diagram that describes the relationship between sediment and production and streamflow (Lane 1955) that was later expanded by Heede (1980) to describe changing streams (Figure 1). A healthy riparian area maintains a dynamic equilib-

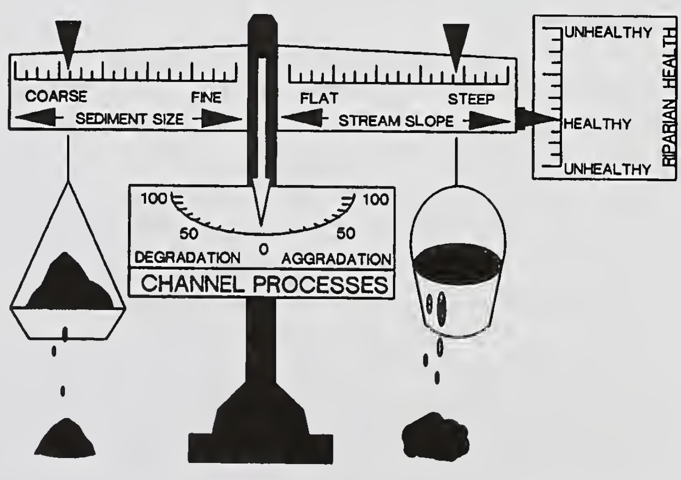

Figure 1. Relationship between sediment and production and streamflow.

rium between streamflow forces acting to produce change and vegetative, geomorphic, and structural resistance. When this natural riparian system is in dynamic equilibrium, it is sufficiently stable so that compensating internal adjustments can occur without producing changes that overwhelm this equilibrium.

It is important to note that the information presented in this state-of-the-art publication did not require any new or unpublished research findings; instead, it was based entirely on a comprehensive synthesis of existing information. While we cannot say that sufficient information exists to address all current and future riparian area issues, there is a need to more fully utilize existing information before establishing future research problems.

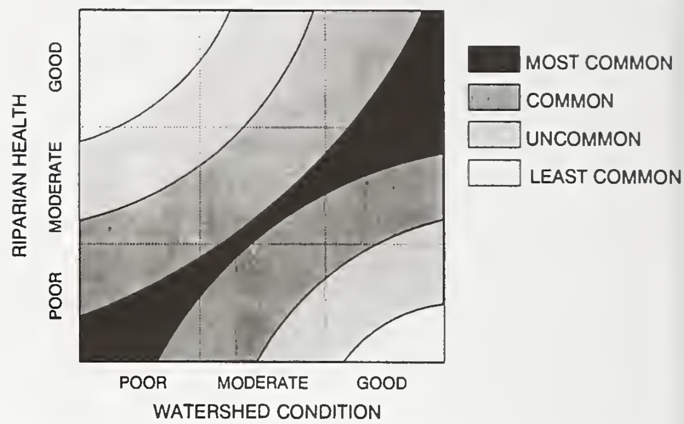

Figure 2. Regions of commonality between watershed condition and riparian health.

Partnership II - Linkages Between Watershed Condition and Riparian Health

The interrelationships between riparian health and watershed condition (DeBano and Schmidt 1989) were further expanded by LaFayette and DeBano (1990). Three concepts are presented along with supporting figures to assist in understanding the relationships between watershed condition and riparian health. The first concept addressed the commonality, or likelihood, of possible combinations of the two factors. The second concept presented the acceptability of these combinations to managers and the public. These two concepts were then integrated into a conceptual framework (third concept) designed to assess existing conditions, specify improvement objectives, and assist in formulating strategies for achieving these objectives.

The balance between watershed condition and riparian health can be expressed in terms of regions of commonality among the different combinations of watershed condition and riparian health (Figure 2). In Figure 2, the horizontal axis represents watershed condition, ranging from poor to good, while the vertical axis shows riparian health, also ranging from poor to good. Combinations of these two axes share distinct regions that are labeled most common, common, uncommon, and least common. These regions of commonality describe the frequency or likelihood that certain combinations of watershed condition and riparian health will occur in field situations. As a result, all combinations are not of equal likelihood.

LaFayette and DeBano (1990) further expand the relationship between watershed condition and riparian health (Figure 2) to include a value dimension, that of acceptability to land managers and the public (Figure 3). Four classes of acceptability are developed: highly acceptable, acceptable, marginally acceptable, and not acceptable.

Figure 4 combines the concepts presented in Figures 2 and 3 and provides managers a framework for assessing current combinations of watershed condition and riparian health. It also provides a framework to formulate guidelines for meeting different management objectives. The horizontal axis represents a range of watershed condition from very poor (-5) to very good (+5). The vertical axis represents a range of riparian health from very poor (-5) to very good (+5). The intersection of the two axes represents a neutral position, where physical conditions are relatively common and acceptable from a management standpoint.

The four quadrants formed by the axes in Figure 4 represent a range of combinations of commonality of occurrence and acceptability to management and the public. The upper right (northeast) quadrant represents a combination of watershed condition and riparian health that commonly occurs and is acceptable under good management. The lower left (southwest) is also quite common but least acceptable to management. Both watershed condition and riparian health are below average in the southwest quadrant. The lower right (southeast) quadrant is less common and less acceptable from a management perspective, and although watershed condition is above average, riparian health is below average. The upper left (northwest) quadrant is least common and not less

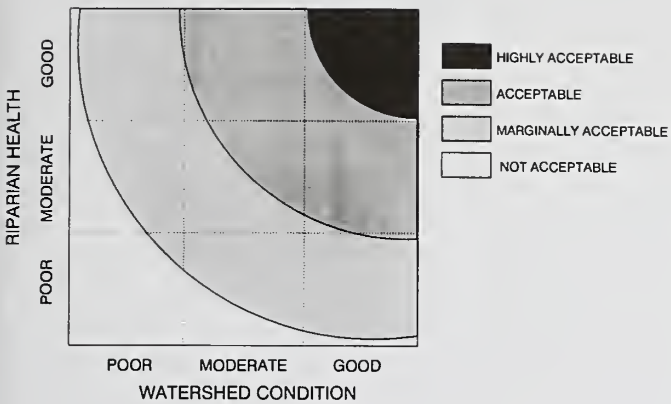

Figure 3. Acceptability of watershed condition and riparian health combinations.

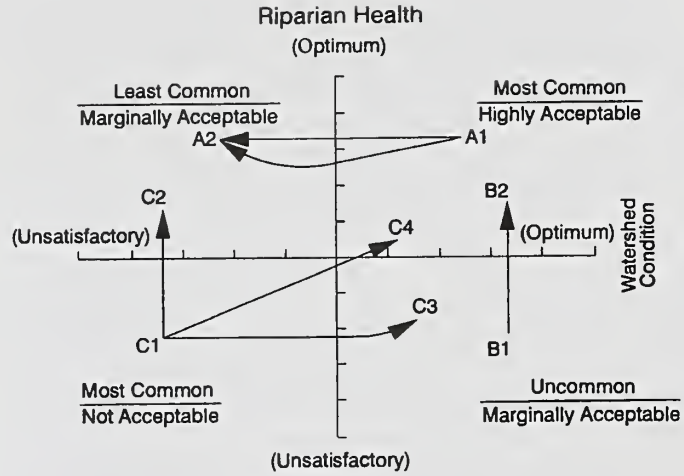

Figure 4. Framework for assessing current combinations of watershed condition and riparian health.

acceptable to management. Watershed condition is below average even though riparian health is above average.

Classifying watershed condition and riparian health within the domain of Figure 4 provides land managers with a method for portraying not only the current status of a given watershed/riparian area but also the consequences of a range in options when managing these areas. Unless an area falls with one factor in a +5 or -5 condition, the area in question can move in any direction in a 360-degree arc. Changes in management can make watershed condition and riparian health either better or worse. Managers may choose to change either watershed condition or riparian health or both simultaneously. Several examples (A,B,C) were used to illustrate this point in the paper by LaFayette and DeBano (1990).

Only watershed condition/riparian health situations existing at position C^1 are discussed here. At point C^1, both factors are well below normal and possibly declining. Management must employ some strategy to improve both factors, either one at a time, or in combination. Treating the riparian area without improving the management of the watershed, as shown by a move to position C^2, is fraught with danger and represents a temporary change. Unless the watershed improves, riparian health is at risk from severe hydrologic responses to runoff events. Treating watershed condition without riparian area treatment is less risky (C^3) and will likely result in a gradual but delayed improvement in riparian health as the watershed provides a chance for the riparian area to recover naturally.

The strategy that will provide for the fastest recovery of both factors is to treat them simultaneously, working in the watershed and along the riparian area. A recovery path toward C^4 is more likely and more acceptable, although probably more costly in the short term. In the long term, however, as the land and channels recover and become more productive sooner, this strategy may prove most cost effective.

Products.--LaFayette and DeBano (1990) reported no new research information, but instead synthesized and conceptualized existing information. The products provided for NFS managers were: (1) an extension of the concept of watershed condition and riparian health into a framework linking watershed and riparian processes, (2) a framework describing some combinations of commonality and acceptability between watershed condition and riparian health, (3) and guidelines for developing rehabilitation strategies based on a conceptual framework describing commonality and acceptability of different combinations of watershed condition and riparian health.

Partnership III - Research Design for Riparian-Stream Ecosystems

Rinne and LaFayette (1991) did report some new research findings, but more importantly, discussed specific concerns relating to research design that must be addressed when conducting riparian-stream studies. They describe four case studies, in Arizona and New Mexico, within the context of research design using intrastream and interstream methodologies.

Intrastream Research Design.--The authors used the intrastream approach was used to determine the effect of grazing on fish populations and their habitats. This is done by conducting studies on contiguous grazed and ungrazed reaches of one stream. Although some differences in abundance and biomass of fish and aquatic macroinvertebrate community composition were found, it was difficult to interpret these differences between grazed and ungrazed stream reaches. Part of this difficulty in interpretation was due to the lack of background pretreatment data. It was problematic to isolate treatment differences from those attributed to natural linear changes in stream morphology, water quality, and solar radiation.

Although many grazing studies have been done linearly in treatments (pastures) on the same stream, there are several inherent difficulties associated with this experimental approach. While this research design removes interstream variability, it is deficient in the context of functioning stream ecosystems. That is, although the terrestrial components of treatments (pastures) are relatively confined and definable, the aquatic components are dynamic. Water, its quantity and quality, and stream biota can change frequently and quickly and are not delimited by strands of barb wire. The influences of spatial relationships of grazed stream reaches versus contiguous ungrazed reaches must be considered in designing research studies. If an intrastream approach is necessary, grazing must be allowed only in downstream reaches.

The research design of an intrastream study involving plant, aquatic biota, or substrate components is further complicated by inherent differences in elevation and associated habitat and flood plain composition. Obligate riparian species are often limited in elevational distribution within a given watershed by such factors as aspect, climate, edaphology, geology, geomorphology and general availability of water. The composition of substrates can change from organism-rich cienegas to sandy, gravelly-cobble types within a short distance. Concomitant stream flows also change abruptly relative to gradient and substrate types. Aquatic biota also change in composition relative to availability of organic and inorganic substrates, vegetation, and flows. Hence, interpretations of changes in vegetation/biotic composition and density or habitat parameters resulting from grazing, or other treatments, are also confounded by the influences of these natural factors.

Interstream Research Designs.--The interstream design was to use paired watersheds to determine the effects of different land uses on stream habitat and fisheries. In one study, fish populations were measured in three watersheds that had been managed differently for more than a half a century. One watershed had been closed to normal multiple uses since the 1930's and was relatively pristine. It was paired with two other watersheds that had been subjected to normal National Forest land uses during the same period. Measurements of fish populations showed no statistical differences between the pristine watershed and the two watersheds under normal multiple use. Reasons for this were attributed partly to inherent differences in geologic strata, watershed exposure, vegetation, and natural variation in fish populations. Also, differences in sport fisheries use between the streams further masked any differences.

Another interstream study used six perennial first-order streams below the Mogollon Rim in central Arizona. Historically, the watersheds containing these streams had been subjected to varied grazing and timber management practices. The least used watershed is one that had not been logged or grazed for over 25 years, but another had been continually grazed and timber had been harvested for years. Preliminary results indicated that stream size, based on mean width and flow, strongly influences fish numbers and size.

The studies reported by Rinne and LaFayette (1991) illustrate that conducting viable research on the effects of the combination of natural- and land-management-induced factors on stream environments and biota in southwestern National Forests is complex. Factors contributing to complexity include: interactions of multiple land uses, spatial-temporal relationships, inability to establish a frame of reference, inability to replicate study areas, jurisdiction in habitat and species management, and frequent changes in land management objectives and direction. Combined, these factors render it difficult to effectively study land management impacts on riparian ecosystems. But, Rinne and LaFayette (1991) pointed out that a stable partnership between research and management personnel can overcome these difficulties and identify research opportunities. Such a partnership operating within the framework of daily forest land management activity will be effective in generating valid, defendable, and applicable information for future management of forest lands.

Products.--The products of the publication by Rinne and LaFayette (1991) for NFS managers were: (1) a conceptual framework for designing fishery and aquatic studies, (2) an illustration of the complexity involved in designing defendable research effort in terms of frames of reference, replication, time, and natural and management disturbances, and (3) increased awareness of opportunities for NFS managers and Research scientists to form partnerships that address riparian-stream ecosystems.

Examples of Other Partnerships.--Less formal, but effective, partnerships have also been established between various NFS and RMS scientists. On the Tonto National Forest (FNF, scientists have designed monitoring strategies for use by District personnel in evaluating offsite effects on threatened and endangered species. Station scientists are largely responsible for monitoring the effects of Arizona's largest wildfire, the Dude Fire of 1990, on water quality, fisheries, and riparian habitat. In these evaluations, information is transferred immediately to NFS managers for inclusion into rehabilitation planning. Likewise, on the Apache-Sitgreaves NF, scientists and forest personnel work hand in hand in collecting much needed information on T&E plant and fish species. They also work together on studies related to productivity of pinyon-juniper woodlands.

These examples serve to demonstrate that partnerships are needed by both parties and can be effective. The products of these partnerships are immediate, although not necessarily highly visible. Information is interpreted by scientists and transferred to field personnel for incorporation into management plans long before the information can be published. This probably is the most important product to be derived from these NFS/RM partnerships.

Keys to a Successful Partnership

Successful partnerships between Forest Service Research scientists and NFS managers strongly depend on identifying combinations of scientists and managers that are committed both to making these partnerships succeed and to establishing mutual priorities. Several interpersonal and organizational considerations involved when developing successful partnerships are discussed below.

Cooperative Attitude.--Both parties must approach the partnership with a cooperative attitude. This includes a willingness to learn from each other and to make allowances for the pressures each is under.

Personal Relationships.--While not mandatory, developing strong personal relationships is helpful in making partnerships work well. These personal relationships help to establish trust and credibility between the partners. The examples discussed earlier all involved strong personal relationships.

Spending Time Together.--Familiarity and the exchange of information between NFS and Research is essential. Opportunities must be provided to spend both field and office time together. This allows both NFS and Research to view and discuss projects, visit sites together, and identify common ideas and issues.

Learning Each Other's Programs.--Researchers need to know more about NFS and vice versa. Understanding how the organizations are similar and different aids in a successful partnership.

Mutual Respect for Each Other.--People in the NFS and Research often hold stereotypical views of each other, many of which are incorrect. Development of mutual respect for each other's abilities and knowledge is essential.

Understanding the Pressures.--Each partner needs to understand the work pressures each struggles under. Researchers often must "publish or perish." The NFS people often have "hard" targets to meet in short and changeable time frames.

Providing Lead Time.--Depending upon the complexity of the project, lead time for research involvement is often needed to line up funding, gather pretreatment baseline data, etc. Managers often want results in unrealistic time frames. Understanding lead time from both parties' perspective is important.

Funding.--Understanding project funding is essential for both parties. Some projects can be done with little funding; others require extra funds to do the required work. As a result, priorities may have to be negotiated and rearranged. Recognition must also be paid to differences between "hard" and "soft" money on the part of both parties.

Assistance in Lieu of Money.--In many cases, NFS personnel may be able to offer assistance instead of funds (e.g., data collection, vehicles, materials, etc.). Research studies are not without substantial

investments in treatment implementation and subsequent monitoring of responses. In many cases, long-term monitoring and measurement will require a mutual commitment and sharing of resources to sustain a complex and long-term evaluation.

Publications.--The NFS managers need to recognize the value of a good publication and assist researchers in publication of useful information. Joint publications co-authored by NFS and Research lends credibility to the work. Publishing good work can be career-enhancing for both parties.

Technology Transfer.--An important final step in a successful partnership is making sure that the information and data that has been collected is analyzed and applied on the ground (i.e., technology transfer). Although publications can be one product of technology transfer, publications may not in themselves assure the successful transfer of the research studies in the time frames required. The application of the technology produced involves a continuing dialogue among the partners until it has been successfully implemented on the ground. Because it is such an important part of the partnership, technology transfer requires the same intensity of commitment and participation as was required for the initial study design, data collection, analyses, and interpretation.

SUMMARY

Various levels and intensities of partnerships between NFS and Research personnel can be established. These partnerships can range from simple consultations and exchange of information concerning monitoring strategies between Forest Service scientists and managers to intensive long-term associations involving detailed research studies. Published papers and other less formal partnerships between RMS scientists and R-3 managers illustrate successful partnerships.

Successful partnerships also may involve several interpersonal and organizational considerations. Some important ingredients are: a cooperative attitude, personal relationships, spending time together, learning about each other's programs, respect for each other, understanding the pressures, providing lead time for funding and other support, and publications. A final step in a successful partnership is applying the results obtained from the research studies to on-the-ground situations. Technology transfer involves a continuing dialogue among the partners until the technology has been successfully implemented. Because of its importance, technology transfer requires the same intensity of commitment and participation as was involved in the initial study design, data collection, analyses, and interpretation.

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Development, Implementation and Monitoring of Riparian Standards and Guidelines

Deigh T. Bates[1]

Abstract.--This paper will discuss the development, implementation and the results of the first year of monitoring of the Riparian Standard and Guidelines and the *Riparian Management Guide* (Gregory, 1990) used on the Willamette National Forest (NF), Pacific Northwest Region.

FOREST OVERVIEW

The Willamette NF is a west-side Cascade mountain forest, of approximately 1.7 million acres, in a rain dominated hydrologic regime in the State of Oregon. The forest extends from the crest of the Cascades in the east, to the edge of the Willamette Valley in the west, it is bounded by the Mt. Hood NF to the north and the Umpqua NF to the south. There are seven ranger districts and a programmed annual harvest as shown in the Forest land management plan of 490 MMBF. Current decisions concerning management of the Northern Spotted Owl and other sensitive species will eventually reduce harvest to approximately 240 MMBF. There are three major river systems on the Forest: the Middle Fork of the Willamette in the southern portion, the McKenzie in the middle and the Santiam in the north.

DEVELOPMENT

When the Williamette NF set about developing a watershed effects model during the early planning process they chose to use, and were fortunate to have, locally developed data. Erosion rate data were developed for soils on the forest and tied to each Soil Resource Inventory (SRI) mapping unit. Much of that work was done on the H.J. Andrews Experimental Forest, Blue River R.D. Stability information that was used in the model was developed by Drs. Fred Swanson and Gordon Grant of the Pacific Northwest Station (Swanson and Grant 1982). The Aggregate Recovery Percentage model was used to determine the level of forest vegetation recovery by watershed (Christner and Harr 1982). This is a method developed on the Willamette NF Finally projected rates of harvest and road construction within the planning period were determined.

The results of that model showed that 13 of the 33 large National Forest System (NFS) level watersheds on the Williamette NF had a good possibility of not meeting water quality standards. The Williamette NF, for the preferred alternative identified in the Draft Environmental Impact Statement (DEIS) and proposed plan, took the attitude that disclosure is the purpose of environmental analysis and disclosed the water quality concerns that surfaced in the analysis process. The response from the public, other agencies and within the agency was one of extreme concern. In order to address those concerns, the Forest chose to concentrate on management of the riparian area as a way of alleviating potential problems with sediment delivery and increases in water temperature and to meet the management goals and desired future condition in the Forest Plan. While the team who originally worked on this issue started from the perspective of dealing with watershed problems it quickly became clear that a number of other resources were going to benefit from these efforts.

With the number of resources that are concentrated in the riparian area the importance of managing that small amount of land area to the best degree possible became apparent and the team chose to develop a guide that would help planners and others to understand the functioning of riparian areas and watersheds in general. To accomplish that goal the

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team contracted with Dr. Stan Gregory of Oregon State University who, along with Linda Ashkenas, a research assistant at OSU, developed the Willamette NF Riparian Management Guide (Gregory and Ashkenas 1990) and coordinated with the Forest to write the Forest Land Management Plan (LMP) Standards & Guideline's (S&G's).

While the title of the publication may seem to indicate a concentration on just the riparian zone it in fact does an admirable job of addressing the functioning of those areas in a total watershed perspective and looks at a variety of potential impacts to these areas - not just timber harvest. The document contains chapters on the resource values associated with riparian areas; landscape level management; basin scale management; harvest unit management, riparian rehabilitation and monitoring considerations.

In the proposed Forest Plan the S&G's had allowed some programmed harvest within the riparian areas, but they were put on a longer rotation than surrounding general forest areas. This was generally the route that most forests in Region 6 took. For example, the Gifford Pinchot NF S&G's allow for 5 percent per mile per decade removal of timber within the riparian area.

Following 7 or 8 iterations of the Riparian Guide, all of which were reviewed by a Williamette NF team, it started to become clear that the best way to handle these areas, especially along perennial streams was to move to the concept of no programmed harvest. The Pacific Northwest Region uses a stream classification system which is basically Class I, II, III and IV, with I through III being perennial and Class IV streams being intermittent or ephemeral. Reference in the following tables to stream class relates to the above.

The supporting reasons for implementing the no programmed harvest within riparian areas are as follows:

1. Provides maximum recognition and protection of riparian dependent resources.
2. Critical component in the region 6 direction to avoid forest fragmentation.
3. Decision making greatly simplified for planners and ground operators.
4. Increases effective management of associated resources of concern.
5. Represents the leading edge in riparian management.

Numerous field trips followed in which the Willamette NF managers took the time to fully understand the implications of making such a decision and to at least preliminarily determine if they were feasible. One area of concern was how much land would be removed from the general forest land base and the tradeoff of timber volume.

Table 1 shows the number of acres for each stream class and other riparian areas that would be involved. Class IV stream acreage was not determined but during the final FORPLAN runs a reduction in available acres was calculated for Class IV streams. The total acreage involved here was 98,782 acres or roughly 5 percent of the available land base. Riparian areas are an unmapped, discrete management area in the forest plan.

IMPLEMENTATION

Application of the S&G's on the ground is guided by the following statement from the Riparian Management Guide rather than being applied as arbitrary distances from the active channel. "For optimal management of riparian resources, riparian management zones should have variable widths that are delineated at ecological boundaries, not at arbitrary distances from the stream, lake or wetland."

No programmed harvest is planned adjacent to all perennial stream or unstable intermittent or ephemeral channels. The recommended riparian management areas (RMA's), as shown in Table 2a for Class I streams are 150-400 feet with an average width of 200 feet. These widths represent the average horizontal width commonly required to meet the management objectives and desired future condition in the Forest Plan.

Stable, moderately stable and unstable Class III and Class IV streams were differentiated by narrowing or even in some cases eliminating required riparian management areas (see Table 2b). The floodplain

Table 1. Riparian management areas.

Stream Class	Length (miles)	Riparian Acres
I	426	19,496
II	940	21,252
III	1,295	29,627
IV	6,621	
Lakes (Shoreline)	270	4,457
Wetlands		23,950

Table 2a. Riparian management guides.

	Class I	Class II	Class III
Range of Width from active channel (ft)	150-400	100-200	50-125
Average Width (ft)	200	100	75-100
Extent of 100 year floodplain within the RMA (percent)	100%	100%	100%
Overstory vegetation remaining within RMA (percent)	100%	100%	100%
Understory vegetation remaining within RMA (percent)	100%	100%	100%
Salvage within RMA	No	No	No

Table 2b. Class IV riparian management codes.

		Intermittent		Ephemeral	
	Stable	Moderate	Unstable	Stable & Moderate	Unstable
Range of width from active channel	0	25-50	25-1000	25-100	
Averge width	0	30	50	0	50
Provide floodplain function	No	No	No	No	No
Overstory vegetation remaining within RMA	None	Partial	Partial	All	Partial
Understory vegetation remaining within RMA	Partial	Partial	All	Partial	Partial
Salvage within RMA	No	No	No	No	No

is assumed to be 400 feet or less on a single bank. If it exceeds this limit the direction is to evaluate the action relative to the Executive Order on Floodplain management.

The Williamette NF experienced a large catastrophic blowdown situation in the winter of 1990. This situation was the first operational test of these guidelines in relation to salvage within the riparian zone. A S&G was written specifically to deal with such situations and directs that salvage can occur only when such salvage is beneficial to the riparian dependent resources. This is a significant change from the past point of view. Instead of asking what can be salvaged and still protect the stream resources, the new attitude is that everything should be left unless riparian dependent resources are in some way benefitted.

Class IV streams were divided into Intermittent and Ephemeral channels and further divided into groupings by the stability of their watershed. Stability was determined from SRI units and a list was published in the LMP appendix. There are two interesting points to note in Table 2b. The first is that stable intermittent drainages and stable and moderately stable ephemeral drainages have no riparian management areas prescribed for them. In essence, what was

said, was that there were no riparian values contained in these drainages that required protection and that harvest activities could be conducted as normal, i.e., within normal contract restrictions. This was one area found to be in great controversy as monitoring activities were conducted. The second point is that salvage within the RMA was not permitted along all of these types of channels. The qualifier as with all of this type of activity was that salvage within the RMA after catastrophic events should be considered only to restore degraded riparian habitat and benefit riparian dependent resources.

RESULTS OF MONITORING

Monitoring of the S&G's took a number of routes. The forest conducted watershed peer group reviews of projects that were recently implemented or that had recent prescriptions written for them. Additionally, the watershed group on the forest developed a implementation monitoring form that could be used by most people on the district as they went about their normal work activities, especially timber sale administrator's and layout people. Specific implementation monitoring was done on each District. The first year did not produce a lot of information with which to work because much of the activities planned under the new S&G's have not been implemented.

The first thing that showed up in the monitoring field reviews was the need to write interdisciplinary prescriptions for the riparian zone. Too often it was found that watershed specialist's alone were writing the prescriptions for these areas without any sort of interdisciplinary interaction. It was taken for granted by biologists and botanists, for example that a watershed oriented prescription would meet their needs. Additionally, there was concern that the hydrologist's were assuming a role for which they were neither trained or educated. While for the most part it was agreed that the prescribed RMA's were adequate there still existed a level of discomfort about having watershed specialists alone do the prescriptions.

The second finding was alluded to earlier and concerns how the S&G's dealt with Class IV streams, especially those designated as stable. While it may be appropriate from a watershed perspective to remove overstory vegetation and still protect watershed resources, from a biological perspective there are serious questions concerning such areas. For instance, the habitat of the Olympic salamander (*Rhyacotriton olympicus Gaige*), a sensitive species, is in those small Class IV drainages and not in the larger ones because it cannot compete with the more aggressive Pacific Giant Salamander (*Dicamptodon ensatus Eschscholtz*). Additionally, there are questions of connectivity and movement corridors from downslope area to upslope.

A second aspect is how Class IV drainages were modelled in the LMP. These streams were not mapped and the Forest Plan analysis reduced suitable acres for unstable Class IV watersheds by 4,703 acres, i.e., no harvest, and by 15,574 acres in moderately unstable Class IV stream, reflecting reduced harvest. In total it reduced the Allowable Sale Quantity by about 9 MMBF. Additionally, there is a S & G that allows for a prescription for a riparian management area if the channel is unstable or will become unstable as a result of harvest. That is, even if the watershed is stable this S & G allows needed protection because of current or anticipated channel conditions.

During implementation it was found that the amount of Class IV streams on the landscape was seriously underestimated during the planning process and that riparian management areas are actually being prescribed for most Class IV streams and in some cases Class III streams, that were missed as well. Detailed examination by one Ranger District on the Williamette NF pointed out these discrepancies. The District had, in detail, examined the differences in the acres excluded from harvest that were modelled in the Forest Plan and what actually happened in one of their planning areas. The area was approximately 8,000 acres and within this they found an 18 percent difference between what the Forest Plan modelled for riparian areas and what was identified on the ground. This is also somewhat conservative because they did not look at all of the streams within the planning area - just those needed to do the prescriptions for the planned harvest. Thus one might expect an even higher discrepancy. The differences came in finding Class III streams that were not identified in the Forest Plan model and secondly by adding Class IV streams that were not identified and also those with unstable channels even if they had stable watershed areas around them. Continuing monitoring will allow the Williamette NF to come to resolution this coming summer of 1993 and the results may require an amendment to the Forest Plan.

It is not realistic to think that all of the Class IV channels can be identified but a better estimate can be made as a result of close examination of the results of our monitoring.

The forth area is how the prescribed widths from the project planning process are put on the ground and how they in turn match up with widths shown in the Plan. While a great deal of data is not yet available overall we are finding that delineated RMA's are minimal in most cases and in some are not adequate to meet desired objectives. An example from the McKenzie R.D. points out the need for close examination and monitoring during and after layout and harvest. Riparian areas were delineated correctly and adequately on the ground and were logged to protect the areas. During yarding operations slash was deposited in the riparian area. Firelines were constructed following harvest that went around the slash, i.e, into the riparian zone, thus indicating that burning was to take place, potentially damaging much of the riparian understory.

The fifth area of concern is around potential impacts to the hyporheic zone. The American Rivers Council appealed many LMP's in the Pacific Northwest Region because impacts to the hyporheic zone were not identified. There is no Standard & Guideline in the Willamette LMP dealing with this area nor does the *Riparian Management Guide* address it. For the most part the current S&G's for floodplain management will suffice but there are areas along the McKenzie River for instance that have old floodplain terraces that are not included in the 400 foot floodplain delineation and from what is understood about these areas they can extend a great distance from the active channel and could be under such terraces. A revision of the *Riparian Management Guide* is anticipated and will include a chapter on hyporheic zones.

CONCLUSION

There are a number of people both in and out of government who are looking at these Standards and Guidelines and the *Riparian Management Guide* for direction. For instance, Congressman Peter DeFazio, D-OR, has included almost verbatim these S&G's in a new Forest Management bill he is currently championing, and the Watershed Option in the Gang of 4 report dealing with Late Successional stands in the Pacific Northwest is based on them but takes another step toward protection. It is my belief that they will serve as a model for regional guidelines in the future.

In conclusion, the Willamette NF is committed to the concept of adaptive management and we believe that policy can only work where monitoring such as has been described above becomes an institutional part of doing business and not just "a nice to do" or a "have to do".

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USDA - Forest Service Policy On Water Rights

Stephen P. Glasser[1]

Abstract.--A review of the federal statutes which instruct Forest Service water resources management policies on lands it administers, with an outline of the specific duties of the Chief, Regional Foresters, and Forest Supervisors.

INTRODUCTION

Water policy changes with changing times, economics, laws, society's values and the relationship between the federal government and the states. It continues to change as states enact instream flow laws, as Congress waffles on exercising its power to reserve water, such as in new wilderness legislation, as courts interpret water right cases, as the President changes.

Policy must change if it is to be helpful to us in choosing correctly among alternative actions or positions. Forest Service water rights policy is found in the 2540 section of the Forest Service Manual.

My job in Washington is to help the Forest Service develop and implement water policies which enable the agency to fulfill its mission, keep us consistent with sister agency water policies to the extent possible, and to provide the technical expertise to the Chief for dealing with water right matters. It is an exciting and stressful job in an era of rapid change!

STATEMENT OF FOREST SERVICE WATER RIGHTS GOAL AND POLICY

One important water resource management goal of the Forest Service is to ensure that the water necessary for proper management of national forests and research areas is available in sufficient amounts and in full accord with legal authority.

To achieve this goal, the Forest Service water rights policy is to utilize one or more of the following six approaches to ensure adequate water is available to meet Forest Service management needs: (1) to develop Agreements or Memoranda of Understanding with States; (2) to appropriate state water rights law; (3) to claim Federal Reserved water rights during adjudications; (4) to Condition special use permits, using Federal Land Policy and Management Act of 1976 (FLPMA) authority; (5) to purchase or exchange of water rights under federal and state law; and (6) Condemnation. Numbers one and four are not water rights per se, but can help provide water.

RESPONSIBILITIES FOR SECURING AND MANAGING WATER RIGHTS

The Chief has the responsibility to develop policies, programs, and procedures for obtaining, using and managing the water needed for National Forest System (NFS) purposes. He must further develop and maintain liaison and cooperative relationships with other agencies and national organizations concerned with water use on NFS lands. Also, he maintains liaison with the Office of General Counsel (OGC) and the Department of Justice (DOJ). He reviews and approves participation in a water rights adjudication; reviews and approves water right claims based upon Multiple Use-Sustained Yield Act or the Wilderness Act prior to their preparation for an adjudication; reviews and approves condemnation actions for water rights.

Regional Foresters have the responsibility to notify states of existing water uses under Federal authorities; to obtain water rights according to state procedures when federal authorities do not apply. Regional foresters purchase water rights or interests in lands with appurtenant water rights as needed. They review and approve water needs analyses by forest super visors. They participate in state adjudications by providing data on current uses and foresee-

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able water needs; prepare and file protests to claims by other parties that would injure water claims or rights of the United States. They must ensure that National Forest personnel have the technical guidance, assistance, and training necessary to prepare water right claims and administer water uses. They further maintain liaison with other federal and state agencies, organizations, and individuals who are concerned with water use. They ensure that up-to-date inventory records on water uses and rights are maintained on a computerized regional database. They coordinate water use and water right activities with adjoining Regions. And they review and recommend a course of action pertaining to condemnation of water rights.

Forest Supervisors have the responsibility to ensure that determinations are made for the specific amounts of water needed to meet present and future consumptive and non-consumptive uses for Forest Service operations and those of its permittees on NFS lands. They also ensure that water is put to the beneficial uses as claimed or decreed when water rights are involved, and that provisions of agreements and memoranda of understanding developed for the management of water resource are met. They propose condemnation actions pertaining to water rights and initiate action after approval by the Chief. They prepare water resource use and water right inventory records for entry into the Regional database.

DETERMINATION OF WATER NEEDS

National Forest staffs are to determine the minimum amounts of water needed at the present and in the foreseeable future to implement Forest Land Management Plans and other statutes which affect the NFS. Include consumptive and non-consumptive (instream) beneficial uses of the water as appropriate. Identify specific sources, including both surface and ground water, for the water needed. Display in Forest Plans a schedule for identifying, and quantifying when appropriate, water needs and the appropriate legal authorities upon which the water claim is or will be based.

Staffs also quantify water needs that can be met under federal law for project evaluations, water right adjudications or in development of state coordinating plans. They also quantify water needs that can be met only through state law at the earliest possible date in states where rights are based on prior appropriation.

Consumptive Uses

Consumptive uses of water for 1897 Organic Act purposes include domestic water for Ranger Stations, fire stations, work centers, housing, and other facilities constructed and maintained for administering NFS programs for watershed management and timber production. The Act covers water for fire protection and control; water for constructing and maintaining access roads and trails for timber production and watershed management activities related to timber production, or for watershed management activities intended to maintain favorable conditions of water flow; water for irrigation of tree nurseries, seed orchards, and other facilities devoted primarily to the supply of timber or watershed protection; water for maintaining Forest Service riding and packstock used in the administration of the NFS timber resources and for watershed protection; and water for special uses where the user is engaged in activities carried out for watershed protection or timber production on NFS lands.

Additional consumptive uses of water which are not related to Organic Act purposes include water for range management including that needed for livestock water; and water for wildlife watering; water for certain recreational uses.

Nonconsumptive Uses

Nonconsumptive uses of water needed to satisfy 1897 Organic Act purposes include instream flows sufficient to maintain the stability of stream channels for favorable conditions of water flow and protection from the loss of productive timber lands adjacent to the stream channels. These uses also include the volume and timing of flows required for adequate sediment transport, maintenance of streambank stability, and proper management of riparian vegetation.

It is Forest Service policy to claim reserved water rights under the Organic Act to the extent these water rights are necessary to secure favorable conditions of water flow, based upon our understanding and the Act's authorities to develop the rules and regulations needed to carry out its purposes, and also upon the

scientific principles of watershed management, including the natural functioning of stream channels. Our policy includes the participation in state water right adjudications and the claiming of the minimum flows necessary to maintain the integrity of the stream channel. Our policy for quantifying channel maintenance flows requires Regions to follow the procedures set forth in Chapter 30 of the Forest Service Handbook 2509.17 unless they request and receive specific authority from the Chief to use an alternate method. Coordinate use of instream flow quantification methods with other Regions, the Washington Office, and the Stream Systems Technology Center to ensure consistency.

It has been Forest Service policy to protect stream channels in timber sale contracts through inclusion of B and C clauses since at least 1929; in other areas where the need exists; and where conditioning of special land use permits is necessary. However, a management decision of conditioning permits is less desirable in securing favorable conditions of flow than where the firmer securing of such flows by means of claiming a reserved water right is available to us in a water rights adjudication.

Other purposes for which water rights may need to be obtained include water to preserve the character or fulfill the purposes of a Wild and Scenic River or National Recreation Area designation; water to support outdoor recreation uses and needs, fish and wildlife habitats, Threatened and Endangered species, riparian and wetland habitats. Use Multiple Use-Sustained Yield Act, Endangered Species Act or other appropriate authorities as the basis of the water right claim for these purposes, with concurrence from the OGC and approval from the Department of Justice.

Wilderness Water Rights

For those Wilderness Areas that lie in the headwaters and there are no private or non-federal lands upstream, Forest Service policy is to not claim a water right for such areas. Rather, we will rely upon the Wilderness Act to control access where only Wilderness lands are involved, and upon FLPMA to condition special use permits to control harmful water developments where only NFS lands are upstream of the wilderness.

For Wilderness Areas that have lands that are not NFS lands upstream in the watershed and where the wilderness water resource could be changed by upstream diversions or dams, federal water rights should be claimed where other authority does not exist to provide adequate protection.

We will follow state water law when that law has provisions for protecting instream flows for wilderness purposes. It is our interpretation that the Wilderness Act requires the protection of the full natural flow minus all existing valid water rights in effect on the date of wilderness designation.

In cases where Congress reserves water to fulfill the purposes of the wilderness area in the enabling legislation, we will follow the provisions of the particular Act. Regarding proposed wilderness areas which are not yet designated as wilderness by Congress, the policy of the Bush Administration was that federal land managing agencies will rely on state water laws to obtain wilderness water rights; that federal land managing agencies will not propose an area for wilderness designation if water is a key resource and sufficient instream flows cannot be assured under state water law; in fact, these agencies will oppose such proposals. Further, we will not request that Congress reserve sufficient water rights for the wilderness; Congress will have to exercise their power to reserve water without our asking them.

Wilderness study area reports prepared in 1992 or later should identify and analyze the water rights situation for the candidate area(s) in light of the policy described in the preceding paragraph.

SECURING WATER NEEDED FOR FOREST SERVICE MANAGEMENT

As mentioned earlier in the policy section, assuring that water necessary for the management of the National Forests is available can be achieved in several ways. Since allocation of water is a state responsibility, it is important to try to work with individual states through cooperative agreements and arrangements as a first priority to ensure needed water allocations. The Forest Service has the exclusive responsibility, however, to manage the National Forests for the maintenance of favorable water flows, for the production of timber, and for other water depen-

dent resources in accordance with the concept of multiple-use management. In meeting this responsibility, the Forest Service has certain administrative authorities, as well as federal water rights arising from federal case law, that can and should be used to manage resources and uses of NFS lands properly. These are State Agreements and Memoranda of Understanding. Where feasible, seek agreements with states to assure availability of water quantities needed for management of the National Forests.

Involve all appropriate state agencies in order to reduce conflicting requirements. Identify Forest Service activities, resources, and projects that require water. Quantify the amounts of water and time period needed. Identify Forest Service authorities that require protection of the water resource and water dependent resources.

State Water Rights

Apply for water rights in accordance with state laws at the earliest possible date where water is not available under federal law and it is needed. File all applications to appropriate water in the name of the United States. For the priority date, assert the date water was first put to beneficial use or the application date, whichever applies. Pay state fees required to secure a water right, provided the fees are clearly not a tax or license. Payments to states for securing water rights under state law shall be charged to the management code of the benefitting function. Refer questionable filing fees to the OGC. Apply for water rights for water used directly by the Forest Service and by the general public on NFS lands. Do not apply for water that is used exclusively off NFS lands. Claim water rights for water used by permittees, contractors, and other authorized users of the National Forests, to carry out activities related to multiple use objectives. Make such claims if one or more of the following situations exist: National Forest management alternatives or efficiency will be limited, or authorities would be threatened, if a party other than the United States holds the water right. National Forest programs or activities will continue after the current permittee, contractor, or other authorized user discontinues operations. Where granting of a water right by the State would adversely affect or injure the present or foreseeable future water uses or needs of the Forest Service, submit a statement to the State agency responsible for water rights that issuance of such a water right would be in conflict with use by United States for National Forest purposes.

Federal Reserved Water Rights and Adjudications

Water rights of the United States, including both reserved and acquired rights, are subject to adjudication proceedings in State courts. The United States can be joined as a defendant in lawsuits to adjudicate water rights within a river basin or other waters under the McCarran amendment.

When properly served in a state adjudication, the United States must submit all claims for water. Failure to do so could result in the loss of rights not claimed. Submit claims for current water uses on forms provided by the state and/or on electronic media in formats acceptable to the state and ourselves, with tabulations of foreseeable uses showing details as required by the OGC. Claim federal reserved water rights under authority of the Organic Act, for all water needed to maintain conditions of favorable water flow and to ensure a continuous supply of timber on all National Forest lands. This includes both consumptive and nonconsumptive uses. Claim the date of reservation as the priority date. Consult with and obtain approval from the W.O. prior to preparing claims for federal reserved water rights under authority of the Multiple-use Sustained Yield Act for water necessary to accomplish multiple use objectives and for which water is not available under State law. The essential factor for asserting water rights under the Multiple-Use Sustained-Yield Act consists of a Regional determination of the Forest Service's ability to obtain the necessary water under state law.

Consider claiming of a federal water right under other authority where water is needed to satisfy Forest Service responsibilities for protection of Wild and Scenic Rivers or as required by the enabling legislation. Claim the effective date of legislative enactment or executive action for rights claimed under other authorities. Apply the reservation doctrine to withdrawn lands reverted to the United States if title never passed from the United States. Seek advice from OGC in cases involving former indian, military, or other reservation lands. The applicability of the reservation doctrine and the effective date is dependent on what is acquired and on

whether the same similar use is continued on reserved lands. Do not claim federal reserved rights on lands acquired by other methods and authorities, such as exchanges, gifts, or purchases if title did pass from the United States at some time. Claim water under state law which is not available under federal statutes or court decisions. Protest water right applications of other parties if injury to a Forest Service water right or application could result and there is a legal and resource basis for our objection. Seek OGC advice first.

Conditioning Special Use Permits using FLPMA Authority

Use authority under the FLPMA of 1976 (43 U.S.C. 1701(note)) to condition special use authorizations to protect instream flows sufficiently to meet on-site and downstream National Forest management needs and values. Include stipulations in special use authorizing documents to ensure the quantities of water needed for fulfilling the National Forest purpose(s), including that necessary for protection of in stream aquatic resources. Granting of a water permit or water right by the State does not give that person the right to occupy National Forest land. Occupancy must be judged consistent with National Forest management objectives, including National Forest water needs, before it can be authorized. Except where easements for agricultural irrigation or livestock watering are involved as part of Public Law 99-545 (See FSM 2729), inform the permittee in writing that authorization does not confer a legal right to the use of water, nor does it provide a basis for acquiring such a right as against the United States. Denial of an occupancy permit based on Forest Service water needs shall be documented in appropriate assessment documents. Assess the cumulative effect of the proposed project in the context of existing projects and those that might reasonably be developed within the same watershed.

Purchase/Exchange of Water Rights and Lands with Appurtenant Water Rights

Section 213 of the Department of Agriculture Organic Act of 1944 authorizes purchase of water rights or lands or interest in lands or rights of way for use and protection of water rights necessary or beneficial for the administration and use of the national forests. Purchase or exchange water rights for the water necessary to meet Forest Service needs when other means are not successful in assuring an adequate supply of water, and water rights are available for sale or exchange. Ensure the purpose of the water use and point of diversion can be changed if necessary.

Condemnation

Use condemnation procedures to obtain water only when no other option is available for assuring the water necessary to meet management responsibilities of the NFS lands. The Chief must approve condemnation actions before they can be initiated.

MANAGING WATER RIGHTS

Forest Service policy is to manage state issued water rights to ensure these valuable properties are not lost by way of mis-use or non-use. Make sure the water is actually put to the use(s) stated in the water right, permit or agreement with the state. Verify the existence and validity of water rights on lands or waters to be acquired before taking land adjustment actions and insure appurtenant water rights are conveyed in the deeds.

Federal reserved water rights cannot be lost by non-use. During water right adjudications and administrative processes for allocating water among competing users, it is important for the Forest Service to review draft water right decrees issued by the State or Water Court for accuracy of Forest Service claims and claims by all other parties which could affect Forest Service lands. File objections as necessary to correct errors, bogus or inflated claims, in a timely and professional manner in accordance with state procedures and advice of the OGC.

Finally, remember that using water rights as a way to try to solve problems related to trespass, special use permits, mining, grazing permits, and land adjustments is wrong. You need to use the authorities stemming from the 1897 Organic Act, FLPMA, National Forest Management Act, National Environmental Protection Act and other statutes to deal with those problems; do not try to use water rights inappropriately!

Geomorphic Effects Of Large Woody Debris In Streams

Richard D. Smith[1]

Abstract.--This paper reviews the geomorphic effects of in-channel obstructions, including large woody debris. It includes discussion of debris flows, debris removal, obstruction-pool interactions, obstruction-channel morphology interactions, mechanisms of pool scour, and scour in obstruction-related pools. Several questions are posed related to information needs required for widespread application of the turbulent scour model in forest streams.

INTRODUCTION

Some aspects of traditional geomorphic thinking need to be modified to fit the special case of forest streams, owing to their unique attributes including: 1) the presence of individual pieces and accumulations of large woody debris (LWD) in the channel, 2) windthrow of large trees along stream banks, and 3) debris flows rich in LWD. The location of debris and debris-related geomorphic features is determined by fluvial processes of bank erosion and transport from upstream sources as well as by several non-fluvial, random processes including windthrow and stem breakage. Beaver activity accounts for additional input (Bryant 1984). Mass soil movements deliver debris from upland areas (Swanson et al. 1976).

The purpose of this paper is not to provide a thorough review of the large body of literature addressing the role of woody debris is streams. Rather, it is to briefly acknowledge key contributions to our current understanding of the geomorphic effects of in-channel obstructions, including LWD, and to discuss recent advances, which commonly involve quantification of concepts presented in earlier literature. Summaries concentrating on the biological function of LWD in forest stream ecosystems include Harmon et al. (1986) and Bisson et al. (1987).

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EARLY STUDIES

Early studies provided conceptual insights and initial quantification of the geomorphic function of LWD. Hack and Goodlet (1960) noted the ability of LWD accumulations to divert flood flow, leading to extreme incision into floodplain deposits. In small forest streams in New England, Zimmerman et al. (1967) documented channel meandering, avulsions, and changes in channel width, owing not to variation in upstream drainage area or discharge but to the influence of LWD. Zimmerman et al. (1967) stated, "Channel form, size, and location are greatly influenced by non-fluvial processes such as tree blowdown, damming by debris, and extension of roots."

Several important concepts were expressed in this early research including: 1) channel width was controlled, in large part, by LWD through windthrow of trees along the banks and flow deflection by tree stems or debris dams in the channel; 2) some LWD pieces defended the channel bed and banks from erosion, while other pieces enhanced erosion by deflecting and concentrating flow; 3) flow energy was dissipated by roughness provided by LWD; 4) LWD induced scouring turbulence, producing channel instability; and 5) LWD affected frequency and duration of overbank flow through effects on channel shape (Zimmerman et al. 1967).

Effects of LWD on channel width in two small, forest streams in the Colorado Rocky Mountains resulted in a very weak dependence of width on upstream drainage area or discharge, contrary to the hydraulic geometry (Leopold and Maddock 1953) relationships of small, non-forest streams (Heede 1972). Expenditure of a large portion of the stream energy occurred over short distances at debris-defended steps in the stream profile, commonly creating a scour pool at the downstream edge of the step (Heede 1972).

In the western Cascades of Oregon, Swanson et al. (1976) noted the tendency of LWD to cause flow convergence, thus scouring mid-channel pools. Deflected flow also scoured pools against stream banks and created channel diversions. Broad, shallow pools tended to form upstream of debris accumulations (Swanson et al. 1976). Bank erosion by debris-deflected flow was an important source of sediment delivery to the channel (Swanson and Lienkaemper 1978).

LWD provides important buttressing of sediment storage sites, commonly accounting for the majority of sediment stored in a channel, which can exceed annual sediment yield by 10-fold or more in small, forest watersheds (Megahan and Nowlin 1976; Swanson et al. 1976; Keller and Swanson 1979). This storage capability is believed to slow the transport of sediment through the channel system (Swanson et al. 1976).

Swanson and Lienkaemper (1978) noted the scouring potential of mobile LWD pieces and accumulations. Debris jams can be transported hundreds of meters downstream during high flows, increasing the erosive consequences of floods and altering channel shape and distribution of alluvium (Swanson and Lienkaemper 1978; Keller and Swanson 1979).

Keller and Swanson (1979) distinguished the effects of LWD accumulations on low-gradient vs steep streams. In low-gradient streams debris jams diverted flow and altered flow hydraulics. This resulted in scour of the stream bed and banks, initiation of bar deposition downstream, and creation of upstream backwater effects leading to meander cutoffs. Debris also influenced the development of bars and channel braiding. In steep streams where development of bars, riffles, and floodplains was inhibited, debris jams provided important sediment storage sites and created plunge pools.

In a small, forest stream in New Zealand, variation in bedload transport rate was largely a function of sediment supply, which was strongly influenced by temporary base levels created by woody debris (Mosley 1981). Debris accounted for important quantities of sediment storage. Episodic releases of this sediment were caused by shifts in debris location.

DEBRIS FLOWS

Debris flows occur in both forested and non-forested channels, however the presence of LWD produces distinctive effects of these mass movements in forested areas. Swanston and Swanson (1976) found that occurrence of these flows depends on volume and stability of LWD in the channel as well as hillslope stability, channel slope, and peak discharge characteristics of the channel. Sudden breakup of large debris accumulations may trigger debris flows, and heavy loading of LWD may increase their erosive potential by enhancing scour of the channel bed and banks (Swanson et al. 1976). Conversely, entrained debris may reduce the travel distance of debris flows in forest channels, resulting in shorter, wider tracks than in non-forest areas (Swanson et al. 1976). Destructiveness appears to depend primarily on volume of the triggering landslide.

Debris flows can leave large, long-lived deposits at channel junctions, alluvial fans, and riparian areas (Benda 1985a, 1985b). These organic-rich deposits alter riparian vegetation and may persist as geomorphic features after stream channels recover from debris flows (Grant 1986). Kochel et al. (1987) observed flood-transported, large tree stems acting as dams confining stream flow and flood deposits such that the channel was aggraded above the surrounding flood plain. Subsequent channel diversion left pseudo terraces above the modern floodplain.

DEBRIS REMOVAL STUDIES

Attempts to further quantify the geomorphic effects of LWD and other in-channel obstructions included several studies investigating the effects of removal of debris. Beschta (1979) reported scour of more than 5,000 m3 of stored sediment along a 250 m reach the first winter following debris removal from an Oregon Coast Range stream. Debris removal also increased turbidity and suspended sediment transport (Beschta 1979).

Removal of LWD from a first-order stream in the White Mountains of Arizona eliminated local base levels imposed by log steps and caused increased sediment delivery through bank erosion (Heede 1985). Formation of new gravel bars at the sites of removed steps replaced lost debris-related hydraulic resistance. Heede (1985) interpreted development of these bars as an indication of increased bedload transport rate.

In southeast Alaska, Lisle (1986a) reported that greater debris loading in clear-cut streams relative to forested sites, owing to timber harvesting activity, resulted in greater total residual pool (Bathurst 1981) length and greater length of channel with residual pool depth providing high-quality salmonid habitat. Removal of debris from the clear-cut sites did not result in statistically significant differences in pool dimensions between treated and untreated sites, owing to large variation between channels (Lisle 1986a).

MacDonald and Keller (1987) reported scour of stored sediment, alteration of local hydraulics, changes in bed surface texture, and changes in the distribution of pools following removal of two large woody debris jams from Larry Damm Creek, northwestern California. Pools were created or deepened at bends above and below the sites of debris removal. Size increase in these pools coincided with a decrease in size of numerous scour pools within the debris accumulations, where a point bar became the dominant sediment storage site.

In order to quantify the effects of LWD on bedload transport and channel morphology, Smith et al. (1993a) removed all woody debris larger than 1 cm diameter from a 100 m reach of Bambi Creek, a small, forest, gravel-bed stream in southeast Alaska. Debris removal resulted in a four-fold increase in inorganic bedload transport at bankfull discharge (Figure 1). This increase was statistically significantly at the 0.01 probability level. Despite early redistribution of the

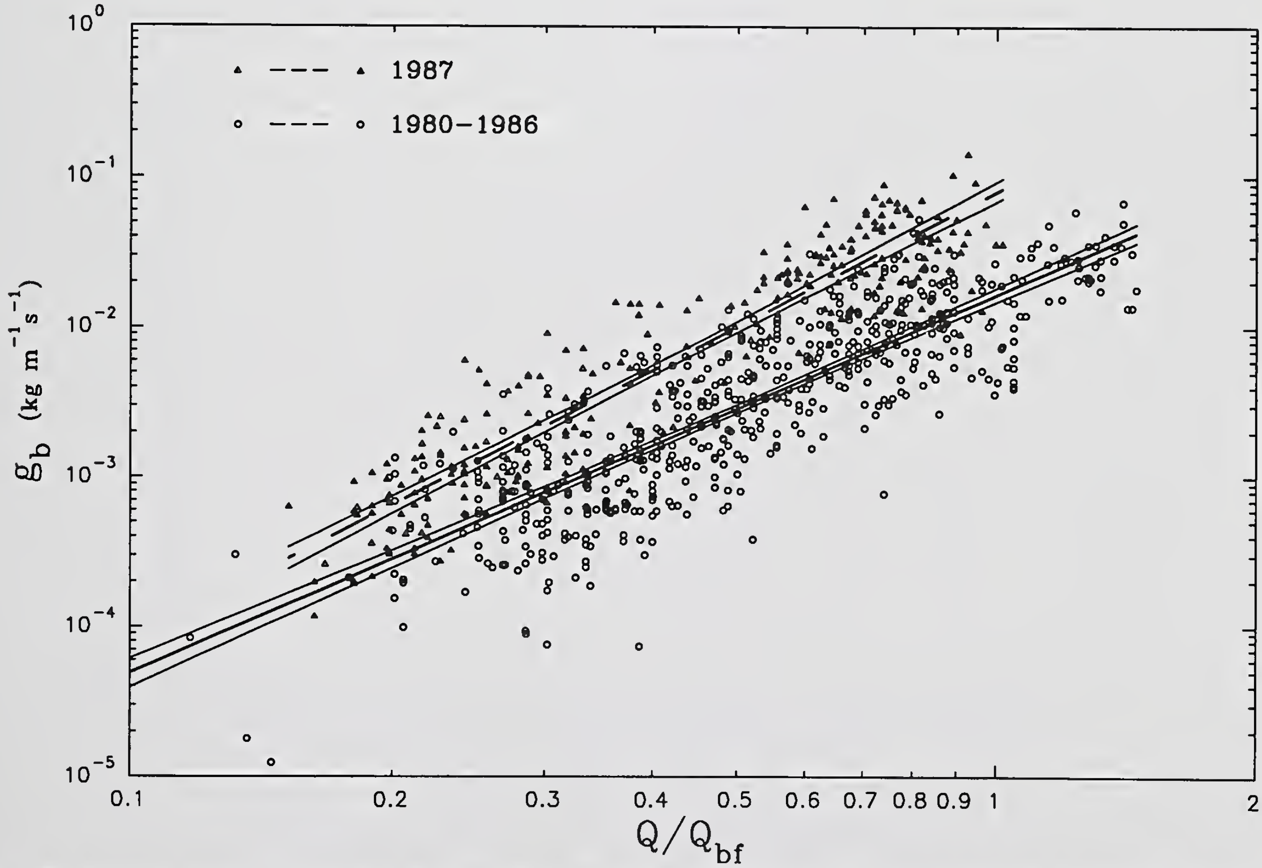

Figure 1. Bedload transport (gb) before (1980-1986) and after (1987) experimental removal of woody debris from Bambi Creek, southeast Alaska showing 95 percent confidence interval estimates. Q is water discharge. Qbf is bankfull discharge (1.7 m3s-1).

most easily-entrained sediment, increased bedload rates persisted throughout the first autumn storm season following treatment. Following adjustment of the stream bed and banks to debris removal, bedload transport is expected to readjust to the upstream load.

Experimental removal of woody debris from Bambi Creek resulted in dramatic redistribution of bed sediment and changes in bed topography, including location of pools and bars (Smith et al. 1993b). Debris oriented in a streamwise direction tended to buttress smaller sediment storage sites than pieces oriented across the channel. Debris suspended above bankfull flow had relatively little effect on the bed or on sediment storage. Marked bed adjustments occurred almost immediately following experimental treatment and continue to the present as sediment is redistributed by storm flows. Adjustments of channel morphology included development of a semi-regular, alternate bar-pool sequence, (Ikeda 1984). Similar sequences are common in streams without the dominant influence of large, in-channel obstructions such as woody debris (Leopold et al. 1964; Church and Jones 1982; Ikeda 1984).

In unobstructed flow in gravel-bed streams, the thalweg commonly flows across alternate bars crossing from one side of the channel to the other at regular intervals, each crossover being associated with one bar and one pool (Leopold et al. 1964; Ikeda 1984). However, in undisturbed, forest streams the thalweg path, location of crossovers and pools, and characteristics of pools are strongly influenced by large debris. In Bambi Creek debris removal eliminated the influence of in-channel debris, and the location of the thalweg and thalweg crossovers became largely determined by the developing sequence of alternate bars and the random location of resistant bank projections (Smith et al. 1993b). Alteration of the flow path redirected flow, eroding banks and widening the channel. Area of undercut banks decreased following treatment, owing to bank collapse and aggradation of alternate bars.

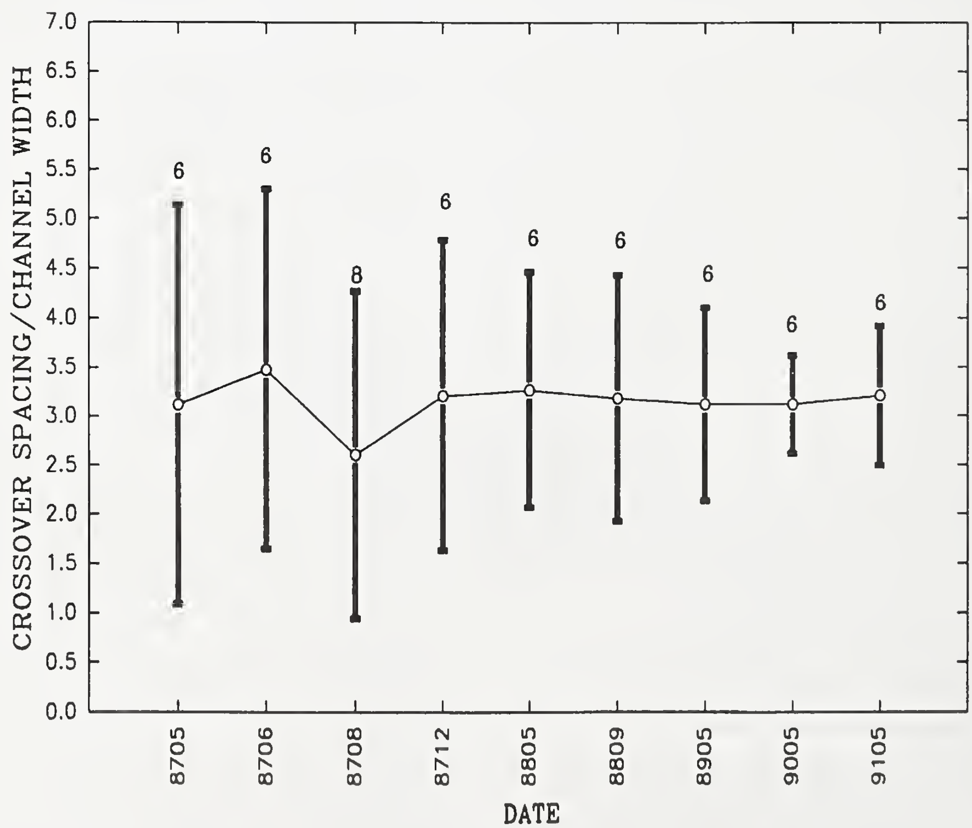

Figure 2. Mean spacing between alternate bars measured as the distance between thalweg crossovers normalized by the mean bed width for Bambi Creek, southeast Alaska. Number of crossovers is given as well as 95 percent confidence interval estimates. Dates are given as year-month (yymm).

Bar spacing, measured as the spacing between thalweg crossovers, fluctuated during the first few months after treatment, but changed very little after the 871203 survey (Figure 2) (Smith et al. 1993b). Variability of spacing tended to decrease following the initial period of adjustment (Figure 2). Bar spacing for the four years following treatment was not statistically different from that prior to debris removal as indicated by overlapping confidence interval estimates. Overall mean spacing for the five May surveys was 3.2 channel widths. Spacing differed before and after treatment from the commonly-cited interval of 5-7 channel widths (Leopold et al. 1964; Keller 1972; Richards 1976) for alternate bars. This difference was attributable to the initiation of crossovers by deflection of the thalweg at resistant bank projections, a common occurrence in forest streams.

In Bambi Creek mean pool spacing was different and more variable between surveys than crossover spacing (Figures 2 and 3), owing to the expected formation of pools downstream of crossovers as well as scour of pools at resistant bank projections (Smith et al. 1993b). Mean spacing of pools varied from 2.6 to 4.5 channel widths for the five May surveys; overall mean was 3.4 channel widths (Figure 3).

Debris removal did not cause consistent changes either in pool spacing or variability of spacing (Figure 3) despite more regular spacing of thalweg crossovers (Figure 2). Pool spacing was consistent with that in other forest streams, such as 1.8 to 6.6 widths for northwest California streams (Keller et al. 1981) and 1.7 to 3.5 widths for streams in the Queen Charlotte Islands, British Columbia (Hogan 1986).

In Bambi Creek the mean residual depth (Bathurst 1981) of pools was variable over time, but did not change in a consistent way as a result of debris removal (Figure 4; Smith et al. 1993b). Experimental treatment did not completely eliminate the effects of debris on channel morphology. Two of the deepest pools were formed where flow encountered debris-defended bank projections, creating bed and bank scouring turbulence.

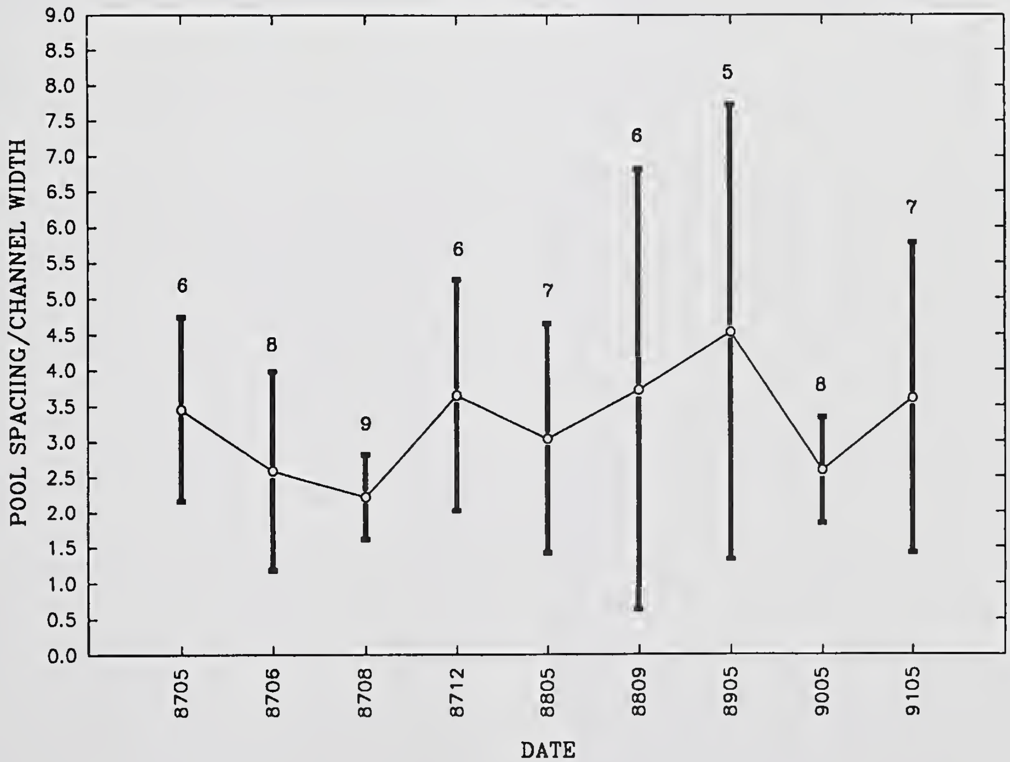

Figure 3. Pool spacing normalized by the mean bed width for each survey of Bambi Creek, southeast Alaska. Number of pools is given as well as 95 percent confidence interval estimates. Dates are given as year-month (yymm).

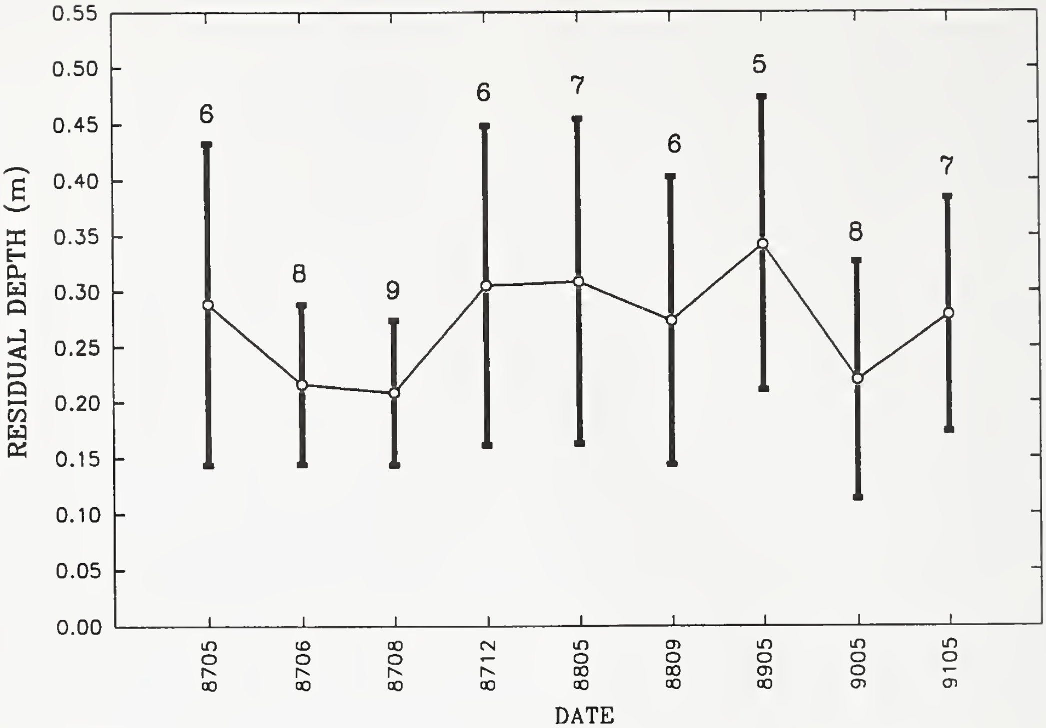

Figure 4. Mean residual depth of pools along the thalweg for each survey of Bambi Creek, southeast Alaska. Number of pools is given as well as 95 percent confidence interval estimates. Only pools with residual depth greater than 0.1 m are included. This restriction affects year to year variation in the number of pools included. Dates are given as year-month (yymm).

In the Bambi Creek experiment, increased bedload transport and adjustments to the channel morphology, were attributable to: (1) elimination of woody debris buttressing of sediment storage sites in the channel bed and banks; (2) elimination of low-energy, backwater zones associated with woody debris; and (3) an inferred increase in boundary shear stress affecting grains on the stream bed resulting from removal of the woody debris component of flow resistance (Smith et al. 1993a, b).

Counteracting these factors favoring sediment mobilization was the loss of scouring turbulence created by interaction of the flow with LWD (Smith et al. 1993b). Following initial readjustment of the stream bed during the first post-treatment year, loss of debris-related turbulence resulted in increased sediment storage within the treated reach (Figure 5). This result was contrary to the common assumption that LWD promotes sediment storage (Megahan and Nowlin 1976; Swanson et al. 1976). Hogan (1987) found that in forest streams in the Queen Charlotte Islands, British Columbia, sediment storage sites were larger but less frequent in channels affected by logging or debris flows. This difference was largely attributable to the tendency for LWD to be oriented parallel to the banks in disturbed channels, thereby storing less sediment except at infrequent, very large sites.

Increased sediment storage in Bambi Creek is plausible given a stream with sufficiently low gradient that alternate bars form. If LWD is added to such a channel, the resulting turbulence could be expected to cause net scour of bed material. In Bambi Creek, elimination of scouring turbulence allowed greater sediment storage than had been provided by debris buttressing and debris- related, low-energy microenvironments (Smith et al. 1993b). Conversely, at slopes greater than those at which bars form (commonly taken as 0.05 but varying with flow depth, grain size, and sediment fabric; Church and Jones 1982) large debris will likely promote sediment storage.

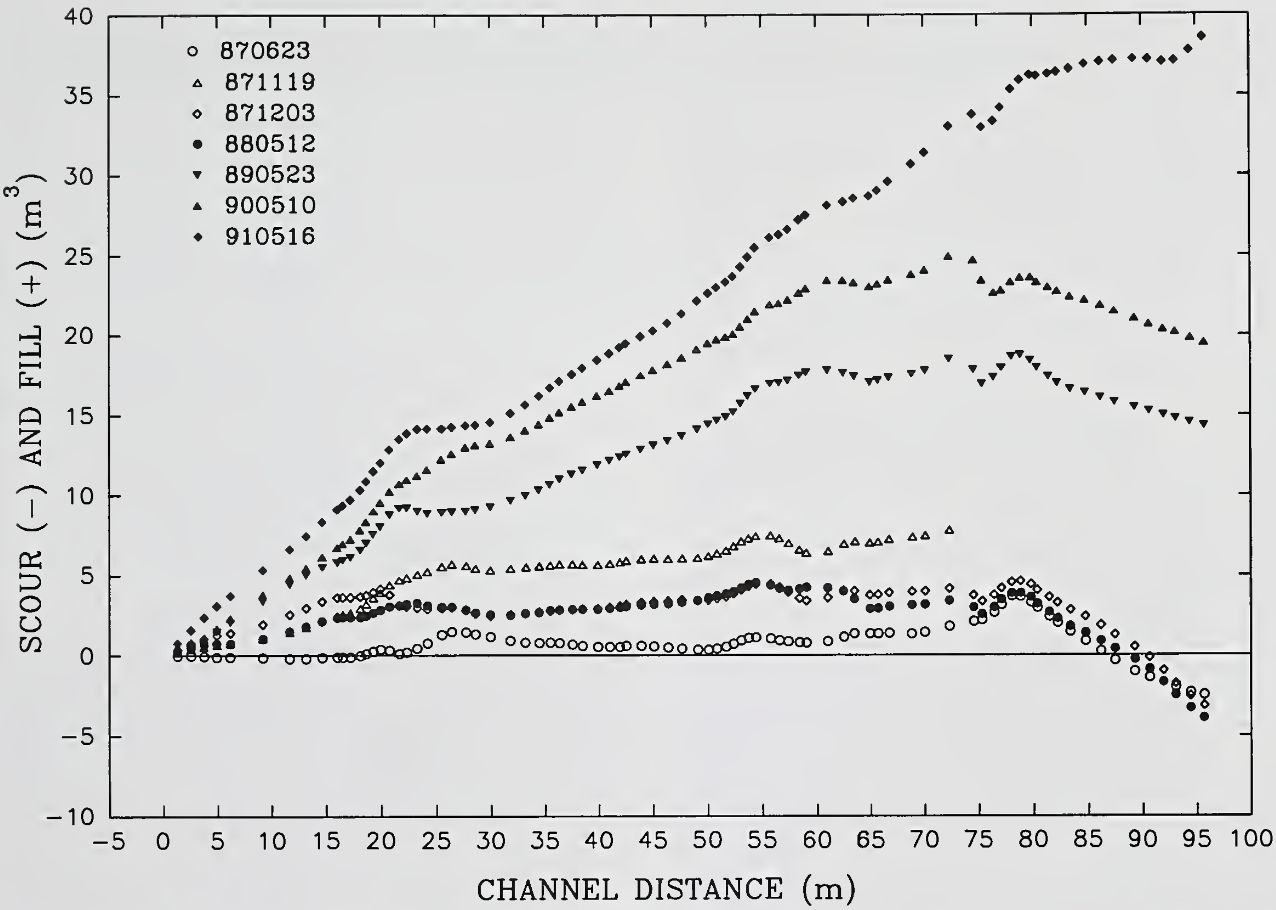

Figure 5. Cumulative change in sediment storage relative to the 870527 survey (datum) for Bambi Creek, southeast Alaska. 871119 was an incomplete survey. Dates are given as year-month-day (yymmdd).

Removal of debris did not result in any apparent change in bar or pool spacing, variability of pool spacing, residual pool depths, or distribution of depths (Smith et al. 1993b). These results were strongly affected by the random placement and characteristics of LWD prior to treatment. Other forest streams may have been more strongly affected depending on pre-treatment volume and characteristics of LWD. Furthermore, development of a bar-pool sequence in the absence of woody debris cannot be expected to occur in all streams. In high gradient channels where bar development is limited by shallow depth (Ikeda 1984), pool habitat may not be replaced by fluvial adjustment of the bed and banks.

OBSTRUCTION-POOL INTERACTIONS

Several recent studies have investigated interactions between large, in-channel obstructions and related pools and bed features. Sullivan (1986) investigated hydraulics and channel morphology in third- and forth-order forest, gravel-bed streams in western Washington. The characteristics of obstruction-created flow constrictions determined the hydraulic characteristics of associated pools, including the variation of velocity in the pool with discharge.

Lisle (1986b) noted that pools in obstruction-dominated streams were linked to obstruction location, and stationary obstructions tended to stabilize pool and gravel bar locations in a northwest California stream. The magnitude of channel constriction and obstruction orientation relative to the flow affected pool size and the stabilization of bars.

Cherry and Beschta (1989) conducted flume experiments investigating the characteristics of bed scour associated with obstructions. Position and orientation of obstructions and channel constriction created by the obstruction were found to affect pool depth, volume, and length of time required for scour.

OBSTRUCTION-CHANNEL MORPHOLOGY INTERACTIONS: ON A REACH SCALE

Hogan (1987) studied LWD in several logged and unlogged basins in coastal British Columbia. Smaller piece size following logging caused a shift in debris orientation from diagonal or perpendicular to parallel to the channel. This shift altered the scouring function of LWD such that fewer deep scour pools were formed. In unlogged channels sediment storage sites were more numerous and smaller, a more stable condition than in logged channels having fewer but larger storage sites generally upstream of debris jams. Smaller debris in logged streams led to formation of less stable debris jams. Reduced LWD loading in logged streams resulted in reduced variability of stream depth, channel width, and sediment texture (Hogan 1987).

Robison and Beschta (1990) evaluated interactions of LWD and channel morphology in a forest, gravel-bed stream in southeast Alaska. Time series analyses showed no periodicity of the longitudinal bed profile, indicating that spacing of pools was irregular and a function of the random spacing of LWD rather than a predictable function of channel size or discharge. Channel width and depth were both found to vary in an irregular way rather than to increase gradually along the channel.

In southwest Washington Bilby and Ward (1991) inventoried 70 stream reaches with variable management history. Compared to managed sites, old growth streams had more and larger LWD associated with a greater diversity of pool types and a greater percentage of plunge pools relative to scour pools.

Smith and Buffington (1992) measured characteristics of obstructions and related pools in several forested gravel-bed streams in southeast Alaska. Sites were approximately evenly distributed between pristine streams and streams clearly depleted of LWD either through forest management practices or experimentation. Multiple, rather than single, obstructions and associated pools tended to complicate relationships between pool and obstruction characteristics. A single obstruction, such as a large log, influenced the development of as many as five distinct pools. Conversely, as many as ten obstructions affected a single pool.

Preliminary results indicated that in pristine streams, where loading of LWD was generally greater, pools made up 48 percent of the wetted channel area (Smith and Buffington in press). In contrast, pools made up only 28 percent of disturbed streams. Scour around LWD obstructions created 80 percent and 46 percent of the pool area in pristine and disturbed streams respectively. In undisturbed streams single logs, rootwads, and debris clusters were by far the most common pool-creating types of obstructions. In disturbed channels non-debris obstructions, such as large boulders or resistant bank projections, played a greater role. However, LWD remained the most abundant type of obstruction. In these channels the few old-growth logs and stumps remaining after timber harvest played an important role in forming the larger, deeper, and more stable pools.

MECHANISMS OF POOL SCOUR

Several studies have investigated processes that maintain the morphology of pools not related to obstructions. The well-known shear stress (or velocity) reversal hypothesis attributes pool maintenance to a reversal in location of maximum boundary shear stress (or velocity) from riffles to pools as discharge increases to approximately bankfull (Leopold and Wolman 1960; Keller 1971). This results in scour and sediment transport through pools and deposition at riffles during high discharge. As discharge recedes, maximum shear stress is again present at riffles and fine sediment accumulates in the pools. The shear stress reversal model is consistent with the results of several studies (Leopold and Wolman 1960; Keller 1971; Lisle 1979; Sullivan 1986; Ashworth 1987; Dietrich and Whiting 1989).

Another approach to the problem of pool maintenance involves modeling the interactive adjustments of velocity, boundary shear stress, sediment transport, and water surface and bed topography in alluvial channels (Dietrich et al. 1979; Dietrich and Smith 1984; Dietrich and Whiting 1989; Nelson and Smith 1989a, 1989b). Studies of the more complex case of obstruction-related pools have not been done at this level of detail.In a gravel-bed stream in New Mexico, Dietrich and Whiting (1989) studied flow and sediment transport through a pool associated with a point bar in a meander bend, but unrelated to an obstruction. They found a reduction in cross-stream sediment delivery to the pool from the adjacent bar as increasing discharge reduced shoaling-induced cross-stream flow. The pool then scoured until the adjacent bar face became unstable, increasing sedi-

ment delivery to the pool, thereby maintaining an equilibrium pool depth. As discharge receded, shoaling-induced cross-stream flow increased bedload delivery from the bar to the pool, resulting in deposition in the pool until equilibrium was again achieved at lower flow. Shear stress reversal occurred as a result of the rapid increase in water surface slope at the pool during rising discharge (Dietrich and Whiting 1989).

SCOUR IN OBSTRUCTION-RELATED POOLS

Nearly all studies of the effects of LWD and other obstructions in forest streams observe that pools are commonly associated with in-channel obstructions. Indeed, obstruction-related pools are the rule rather than the exception in these small, gravel-bed streams (Keller and Tally 1979; Lisle 1986a; Robison and Beschta 1990). Mechanisms by which obstruction-related pools are formed and maintained are not necessarily the same as those for pools not related to obstructions. If hydraulic processes in these pools differ from those in non-obstructed flow, then patterns of channel morphology and routing of sediment in forest streams may differ substantially from streams in other environments.

Beschta (1983) conducted flume experiments investigating hydraulic conditions in obstruction-related pools. Obstructions created a wide variety of hydraulic environments ranging from zones of scouring turbulence to low-velocity, backwater areas. Pool depth and size were functions of complex interactions between obstruction diameter, obstruction position above the bed, and flume discharge. Flow underneath obstructions lying on the bed was an important scouring mechanism. For these cases, larger obstructions created deeper pools. For obstructions elevated above the bed, rate of increase in pool depth with discharge peaked when flow overtopped the obstruction.

Beschta (1983) reported that obstructions created zones of exceptionally high turbulence capable of scouring and removing gravel, even though temporal-mean, near-bed velocities indicated otherwise. This observation indicated that entrainment with rising discharge may be caused by an increase in obstruction-related turbulence rather than increased average shear stress; therefore the shear stress reversal mechanism may not be required to maintain pools formed by scour at obstructions.

Lisle (1986b) drew attention to the analogy of scouring, pool-forming processes associated with naturally-occurring obstructions to similar processes at bridge piers. This insight encouraged utilization of a very large quantity of laboratory research simulating fluvial scour around piers. In these studies, large-scale vortices were found to be the primary mechanism of local scour (Breusers et al. 1977). Downward flow in front of the pier induced a "horseshoe vortex" that wrapped around the pier near the bed (Tison 1961). Vortices with low-pressure centers were cast off from the pier, lifting mobile sediment from the bed with the generation of each vortex (Breusers et al. 1977).

Laursen (1962) described equilibrium scour conditions in pier-related scour holes as a balance of sediment discharge into and out of the scour hole. Increases in discharge resulted in increases in erosive force upstream of and in the scour hole, maintaining depth of scour. Bed material was mobilized by a combination of time-averaged boundary shear stress and turbulent agitation both ahead of the pier and in the lower portion of the scour hole (Melville 1975, 1984; Breusers et al. 1977; Melville and Sutherland 1988). Downward flow and vortices scoured pools at average shear stresses less than those required in the absence of obstructions (Tison 1961; Carstens 1966; Breusers et al. 1977). Bed scour near a pier was found to begin at velocities as low as 42 percent of the critical average velocity for material transport in the undisturbed part of the stream (Carstens 1966; Breusers et al. 1977).

Smith (1990) investigated hydraulic conditions in and around an obstruction-associated pool in a field setting by measuring boundary shear stress, scour and fill of the stream bed, bedload transport rate, and bedload grain-size distribution. Rate of increase with increasing discharge of the temporal-mean, near-bed velocity and boundary shear stress, computed from velocity, was statistically the same at the pool as at pool head and pool tail locations (Figure 6). There was no tendency for near-bed velocity or shear stress in the pool to exceed that at the pool head or tail for flows as large as 1.4 Qbf. In this respect, the pool clearly differed from pools not related to obstructions where the shear stress reversal model has been found to apply.

Scour and fill at this field site did not follow a systematic trend of pool filling at discharges below bankfull and scour at higher flows. Rather, scour and

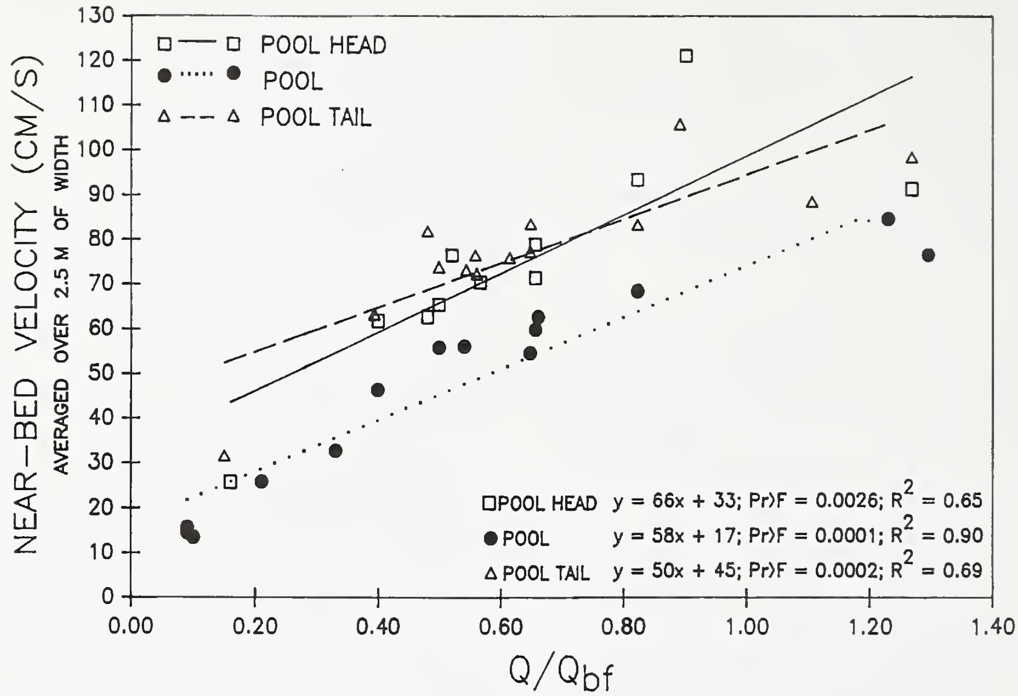

Figure 6. Variation in near-bed velocity with dimensionless discharge for Tom McDonald Creek, northwest California. Q is water discharge. Qbf is bankfull discharge (3.6 m3s-1).

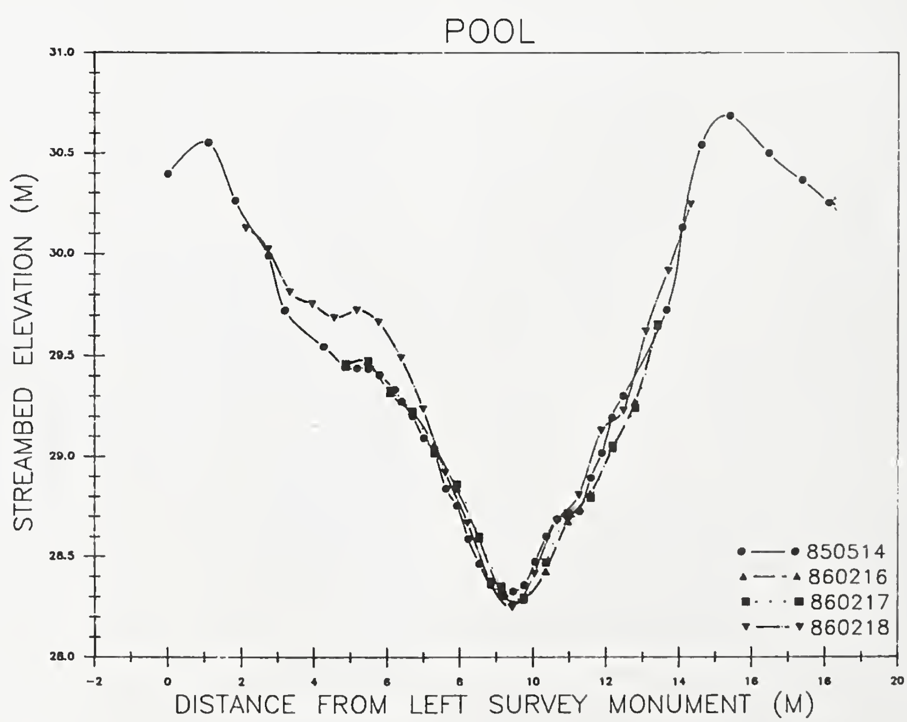

Figure 7. Cross-sectional soundings at Tom McDonald Creek, northwest California. Discharge at the time of the surveys ranged from less than 0.2 bankfull (850514) to greater than 3.5 bankfull (860217). Elevation is relative to an arbitrary datum. Dates are given as year-month-day (yymmdd).

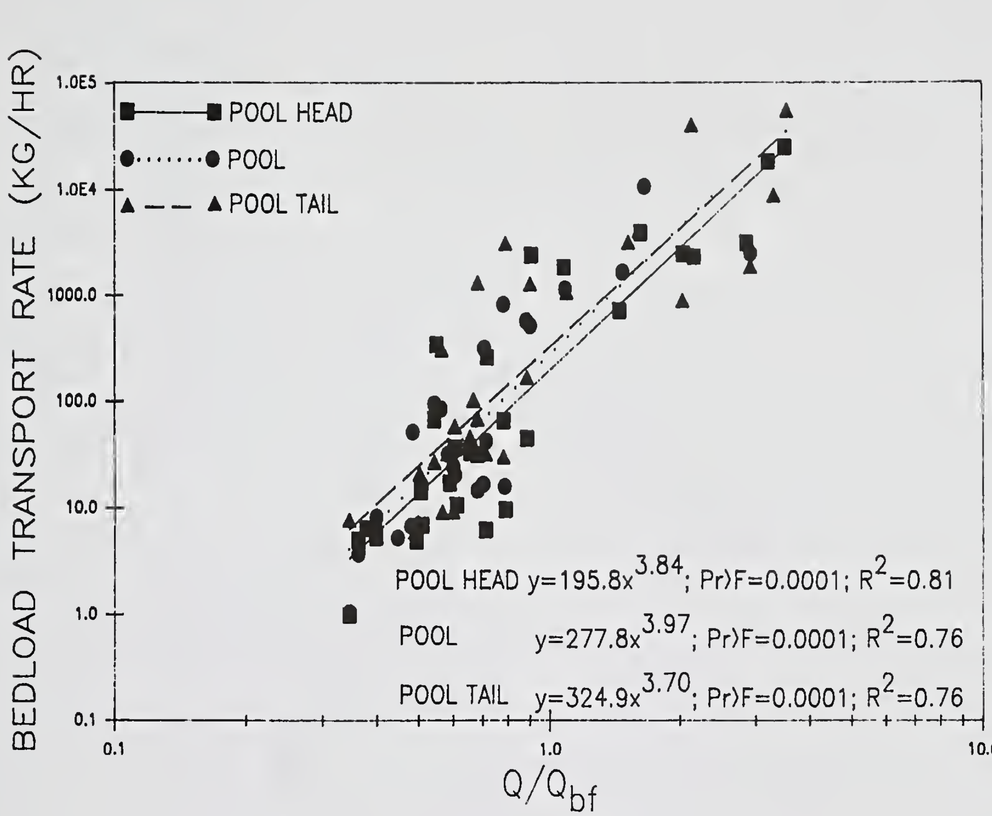

Figure 8. Variation in bedload transport with dimensionless discharge for Tom McDonald Creek, northwest California. Q is water discharge. Qbf is bankfull discharge (3.6 m3s-1).

fill occurred in response to inferred changes in sediment supply, throughout a wide range of discharge. Both scour and fill in the pool, calculated from soundings and from import and export of bedload, occurred well above and well below bankfull discharge in cycles varying in time from several minutes to several hours and on rising as well as falling hydrograph limbs. Scour pool morphology changed little in spite of large, sediment-transporting storms with an associated bedload flux much larger than the volume of the pool (Figure 7; Smith 1990).

No systematic spatial reversal of maximum bedload transport rate or of bedload competence with increasing discharge was observed, indicating that, through a wide range of discharge, total erosive force in the pool was similar to that at the pool head (upstream sediment supply section) and pool tail and that bedload was transported without discharge-dependent changes in pool storage (Smith 1990). The range in magnitude of bedload transport was similar, and Increase in bedload with discharge at the pool was not statistically different from increase at the pool head and pool tail (Figure 8). Competence was measured as the mean diameter of the five largest bedload clasts in each composite sample. Competence at the pool was not statistically different from that at the pool head or tail (Figure 9; Smith 1990).

Similarity of bedload transport rate and competence at the three cross-sections implied that total entrainment force at the pool was underestimated by time-averaged shear stress alone (Smith 1990). Therefore, mean stress in the pool must have been supplemented by additional tractive and lift forces resulting from instantaneous turbulent velocity fluctuations and vortices created by interaction of the flow with the LWD obstruction in a manner similar to flow around bridge piers. This combination of temporal mean shear stress and instantaneous turbulent forces created and maintained the pool at a site where a pool may not have formed in the absence of an obstruction. Smith (1990) summarized these hydraulic conditions as the conceptual "turbulent scour" model of pool maintenance. This model accounted for the observed balance, over time periods much shorter than the duration of individual storm hydrographs, of bedload import and export from the

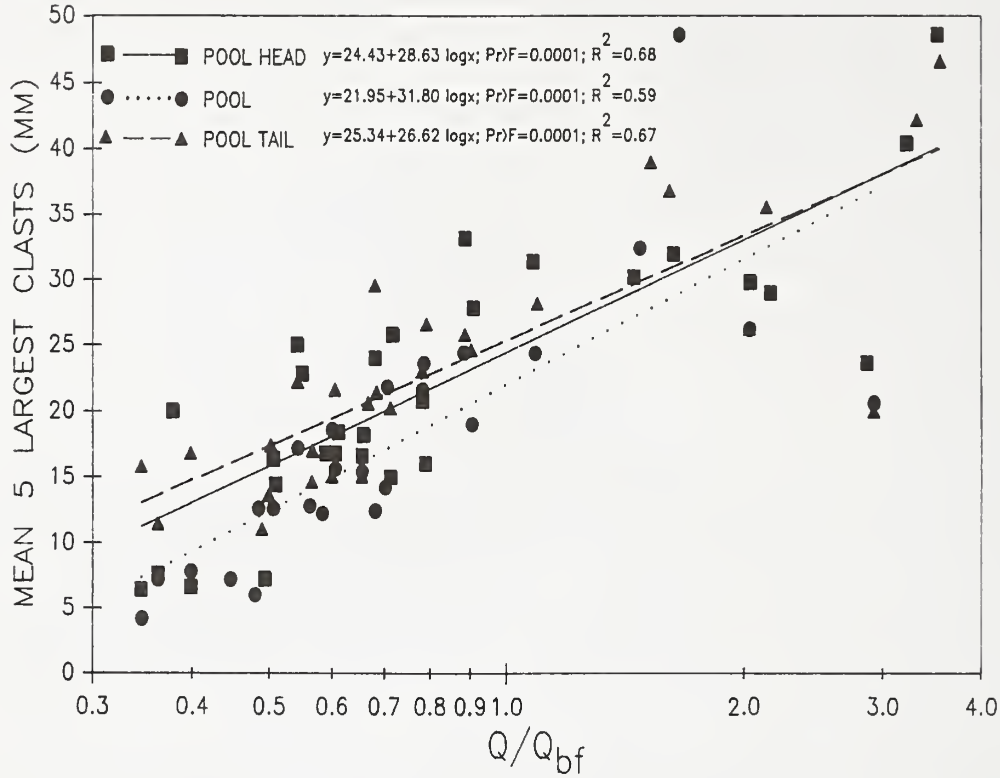

Figure 9. Variation in competence with dimensionless discharge for Tom McDonald Creek, northwest California. Competence was measured as the mean diameter of the five largest clasts in each composite bedload sample. Q is water discharge. Qbf is bankfull discharge (3.6 m3s-1).

pool, in response to apparent changes in sediment supply. This explained the approximately constant pool morphology despite bedload transport rates as large as 8300 kg hr-1m-1.

Application of the turbulent scour model to alluvial, gravel-bed streams in forested environments suggests that random input of LWD can be a dominant factor, perhaps as important as temporal-mean hydraulic variables and sediment grain-size characteristics, affecting local pool morphology and local bedload transport dynamics (Smith 1990). However, size and shape of LWD pieces and clusters in streams vary widely, as do geometric relationships of obstructions to scour pools. Extrapolation of results of this study to other obstruction-pool geometries is untested.

If the turbulent scour model describes a process widespread in forest streams, several related questions need to be addressed including; 1) In streams where LWD obstructions are common, is bedload transport initiated at lower shear stresses and, therefore, more frequently than in other streams?; 2) If transport rates are more dependent on sediment supply and less dependent on mean hydraulic variables, are commonly-used bedload transport equations likely to provide meaningful estimates?; 3) Does exogenous control of channel morphology and bedload transport, in the form of random input of LWD, decrease stability of channel morphology?; 4) Does it increase variability of bedload transport rates?; 5) Does cyclic scouring from obstruction-related pools contribute to commonly-observed pulses in bedload transport?; 6) What effect does the presence of LWD have on frequency, size, depth, and distribution of pools and gravel bars?; and 7) Are obstruction-related pools more likely to persist and recover quickly from high-magnitude sedimentation events, (i.e., do they decrease the sensitivity of streams to disturbance)? Understanding the answers to these questions and other geomorphic effects of LWD is vital to future management of forest lands, particularly with respect to understanding stream channel response to management impacts, assessment of stream sensitivity, prediction of cumulative watershed effects, and evaluating processes affecting aquatic habitat.

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Some Notes on Hydrology In The U.S. Forest Service

Luna B. Leopold[1]

Abstract.--A statement of the unique role of the field hydrologist in National Forest management is provided, with discussion of how duties of the hydrologist can be perceived to take a secondary role in comparison with the traditional duties associated with basic silviculture, timber cutting, road construction, and trail maintenance. The paper concludes with a discussion of a new field program for mapping forest gaging stations designed to expand and sharpen the insight of the hydrologist in useful and rewarding ways while observing the unique qualities of the hydrologic landscape.

This is a meeting of the forest hydrologists of the U.S. Forest Service. I am told that one purpose of the meeting is to emphasize the important role of forest hydrology in the management of the National Forests. To serve that purpose the Service may have assembled the wrong audience. Perhaps the audience might better have been the forest supervisors and the regional foresters.

We, the hydrologists, do not have to be told why our discipline is important in forest management. Many of our supervisors have to be told. Nevertheless, because our role has not been appreciated it is necessary to stand back and ask ourselves why we are not much understood. We have the responsibility to show the supervisors how we can contribute. This places a premium on building a strong technical competence in our own group.

In addressing this question, I would like to break the subject into several components and make some specific suggestions regarding how our role can be upgraded and how we can become more relevant to the administration.

I will begin with a statement of the present role of hydrology. In the forest headquarters, hydrology has only soft targets compared with silviculture, timber cutting, road construction, and trail maintenance. As a result the hydrologist is shunted from one job to another, to budget preparation, to monitoring reports, to forest plan writing, to analysis of a timber sale area, to estimating cumulative impact, to study of environmental impact. Indeed, the jobs to which hydrologists have been assigned encompass the whole of the duties of forest administration.

In my analysis of this problem. I have not found even a single example of a hydrologist assigned solely to analyses of problems in straight hydrology. There may be a few but I have not found one.

The fact that there are only soft targets gives the opportunity to do some creative things because no one in the administration knows just what the hydrologist is supposed to do. Therefore, it is up to us to have a simple and modest plan to do two essential things: to prepare informative and useful analyses that have significance in the management field, and to train ourselves to use the varied techniques available in our field to contribute to that desirable end.

This is not simple because we first have to be able to use the various available techniques before we can produce the significant and useful analyses that I visualize. Of course many of the forest hydrologists can do these things very well but there are too many who do not have either the training or experience. There are persons in the job of hydrologist who have a degree in say environmental science who had only

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a single course or maybe no course at all in surface hydrology, to say nothing of a background in groundwater hydrology.

Let us begin by mentioning a few things that make us important to the Service. This little summary might begin with looking at it from the standpoint of the forest managers.

If the forest supervisor asks us why we are important to him, what do we say? There are several things we would say.

The hydrologist can see in the field if the streams are in good or poor shape. We can assess in the field whether our activities are within the scope of the universe within which the watershed can accommodate changes or whether the ecosystem cannot absorb the changes we are imposing on it. Maybe we cannot do this at the moment on a quantitative basis but we at least know what are the indicators. We can see in the field the pattern of streams and judge in a general way whether the pool-riffle sequence appears normal or unusual.

We can analyze the data from measuring stations and discuss the probability of different magnitudes of events. We can show how field measurements of infiltration capacity can be used to infer conditions with respect to overland flow. We can see whether Hortonian or saturated overland flow is the principal process.

We can evaluate the effects of land use on the speed of runoff as measured by lag time from rainfall to runoff.

We can map vegetation types and draw some conclusions about runoff processes as they affect erosion. We know the quantitative values of normal and excessive sediment discharge. We can sample bedload and suspended load and interpret the sediment rating curves derived from such measurements.

These data and interpretations are useful in management decisions but unfortunately are usually not so recognized by the superiors. In part it is because there is a large gap between possibilities and realities. We hydrologists are not living up to our potential. We are important but we have not made it obvious to the upper echelons.

There are a large number of hydrologists who can do all the things I have mentioned and many more. But these experienced people are in the minority. It is not the fault of the rank and file that they are somewhat short of the necessary skills. The Service gives most of you but little time to learn hydrology on the job. Even more lamentable, the forest hydrologist is not encouraged to make observations in the field nor to carry out long term programs of field measurements. Hydrology is not just an office pastime on a computer.

The experienced among us should validate programs to upgrade the skills of the less well-trained. The regional hydrologists have a special responsibility in this connection because the less-experienced need not only guidance but continuing encouragement.

My focus is to face this situation head on, recognize the reality, and provide a practical program for upgrading our capabilities. We cannot depend on the establishment to do this.

We must deal with the situation individually and personally. We must do the work necessary to increase our knowledge, gain experience, and learn to read the hydrologic landscape in the field.

Let us look at some of the things that we might do. It must begin with training ourselves to utilize the principles of hydrology that have been developed over the years. Whether or not the job description explicitly states it, hydrology is a discipline that requires hands-on collection and utilization of data. This can be as simple as the placement of a thermometer out on the porch and reading it every morning. The next step of higher value and sophistication is to buy a plastic rain gage for 3 dollars and putting it out on the front lawn to be inspected each time it rains. You may think this is too simple to be hydrology but I can assure you that it is the very essence of the hydrologic business. By the way, a rain gage can be also made from a coffee can. In this case buy a baby bottle from the dime store; most baby bottles have graduations in cubic centimeters and so you can pour the rain water into the baby bottle, record the cc volume, then change the number into inches of rain.

There is no substitute for direct observation of some field quantities. The next and most profitable step insofar as learning is concerned is to place a staff gage in the nearest creek, gully, or channel and read the gage at certain times. If you are lucky enough to live near a creek or have your office near one, it might be possible to place the gage where it can be seen

from your window and read through binoculars. You can make a staff gage out of any old piece of wood, lettering or burning on to it a scale of gage height in feet or centimeters.

Now once you are reading a staff gage you are into the crux of the hydrologic science because it is then necessary to construct a rating curve and measure stream velocity. Obviously this requires that a crosssection be surveyed, a bench mark established, and velocity measurements be made at various stages of flow. The easiest way to measure velocity is by floats and the best float is an orange peel. It has just the specific gravity to float nicely at the surface, it is brightly colored and thus easily seen, and is readily available. Multiply the surface velocity by 0.8 to change the surface velocity to approximately the mean velocity.

You can ask why all this elementary stuff should done. It is a great learning experience and it is very interesting. Then if the creek that you have chosen to observe is related to your forest, you are already in the business of monitoring. one of the tasks mandated by law for every national forest.

I have been teaching hydrology for years and I can assure you that the observation program outlined, carried out with reasonable care, is without doubt the most effective way to learn hydrology. The field program can be extended, of course, to include observation of water level in wells, soil moisture, and many other aspects of the science. But for most busy people keeping a record of rainfall and stream discharge is the easiest and most fruitful task.

Note that all the things recommended so far can be done in one's spare time and need not use any office time. On the other hand, any office that fails to encourage its staff to engage in such useful and interesting training would be truly negligent.

All this may sound childish and only for the beginner. Simple it is but not unimportant. I have been in this game for a long time and yet I keep my little staff gage and the plastic raingage in my yard and make observations on a routine basis during storms. I find that I keep learning things.

Now turning to a specific program that I have written in detail and recommended to all forest hydrologists regardless of rank and experience. It consists, in brief, of the following parts.

Locate every gaging station in or near your forest. Obtain the unpublished data on the velocity measurements for the period of record. Go to each station, survey a crosssection, survey a profile of the water surface, establish a benchmark, install a staff gage, make a velocity measurement, begin a rating curve, make a pebble count, make a sketch map, identify and sketch the terraces if they exist, identify and flag the indicators of the bankfull stage, and survey them in on the profile, and classify the channel type.

Such a program is estimated to take no more than two weeks, visiting all the gaging stations in the vicinity. After the field work, the data would be used to construct frequency curves, regional geometry curves and rating curves.

This program has been criticized as unnecessary. Some say it is not needed because all the hydrologists have done such things already and it would be a waste of time. I doubt if more than a few forest hydrologists have personally visited all the gaging stations in their forest and analyzed the data as recommended.

It can be asked how this program can improve skills that are need to do the kind of work mentioned earlier as important to the forest supervisor. A field program makes a person see things in a new way, develop a sense of the value of data, sharpens insight. Analysis of observational data teaches procedures such as statistical evaluation, flood routing, limits of confidence, and computation of quantities need for evaluation of field conditions. And initiative shown by demonstrable effort to increase skills will not be lost on supervisors.

The hydrologist has one of the most interesting and useful jobs in the agency. The position and the work can be made increasingly useful and enjoyable by assuming a role not mandated by the job description, but pursued for the mere pleasure of improving the mind.

Merging NEPA and Hydrology

Ann Puffer[1]

Abstract.--An overview of water resource involvement in planning for timber harvest and road building activities are given, with emphasis on less well-established procedures for determining effects from mining and grazing. The paper also provides background on how the information might be incorporated into a National Environment Policy Act (NEPA) document, as well as a brief overview of watershed effects and general analysis concepts.

INTRODUCTION

One challenge facing Forest Service hydrologists is how to take all of the information they gather on water resource function and stream channel morphology for a project and then incorporate it into National Environment Policy Act (NEPA) documents. This paper addresses this challenge by providing some guidance on merging hydrology with NEPA. The discussion focuses on water resource involvement during planning for timber harvest, road building activities because the procedures for documenting effects from these activities are well established. Less-well established are determining effects from mining and grazing, yet water resource input to this activity occurs rather frequently.

Prior to discussing how the information would be incorporated into a NEPA document, a brief overview of water effects and general analysis concepts are necessary. This will help to set the stage for why various information is recommended to be incorporated into the NEPA document.

WATER RESOURCE EFFECTS

Water Resource Effects (WRE) include all effects on the water resource and beneficial uses of water that occur both at the site (direct effects) and away from the location of the actual land management activity and transmitted through the fluvial system (indirect effects). WRE result from the combined effects of one or more management actions within a drainage basin. Cumulative effects may result from changes in watershed hydrology, sedimentation rates (landslides and/or surface soil erosion), and temperature and chemistry. Indicators of WREs vary, depending on watershed characteristics, climatic regime and water related values of concern. Examples include changes in stream channel morphology, including aggradation or degradation of bedload sediments, and lateral scour of stream banks; and chemical water quality changes such as acid runoff from mines or various chemicals from herbicides/pesticides. The general procedure for evaluating WRE requires evaluation of the steps shown in Table 1. What follows is an explanation of each of the steps.

The first two steps is to identify beneficial uses and determine water quality criteria necessary to protect each use. This information is obtained from the state water quality standards. States have designated beneficial uses that are to be protected by

Table 1. Water Resource Effects analysis process.

- Identify beneficial uses of water
- Determine water quality criteria necessary to protect each use
- Determine drainage basin size for analysis
- Determine watershed characteristics
- Identify important WREs mechanisms
- Develop watershed history
- Identify proposed management actions, including mitigation
- Identify reasonably foreseeable future management actions
- Evaluate WRE of each management alternative

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stream segment. In addition, state standards define water quality criteria that are necessary to meet in order to protect each designated beneficial use.

The third step is to determine the drainage basin size for analysis. WREs are generally proportional to the acreage of a drainage basin that has been, is, and will be disturbed. A general rule of thumb in delineating the downstream most point for evaluating WREs is to use the point at which the effects become "diluted." Dilution can be in terms of actual dilution by water as a tributary stream flows into a mainstream or where land management activities are occurring to such an extent along a stream channel that the effects of the proposed or future activities would be "masked" by them. Further discussion of this may be found in MacDonald (1989).

Fourthly, determine watershed characteristics. This entails defining items such as natural sediment rates, geology, soils, climate, aspect, erosion rates, and landforms. Additionally, identify water quality characteristics.

Fifthly, identify important mechanisms for WREs. Based on the watershed characteristics, identify relationships such as dominant geomorphic processes within the basin (i.e., mass failure, soil creep), and stream channel functioning (fluvial geomorphology).

The sixth process involves developing a drainage basin history. This includes identifying all land management activities that have occurred and are currently occurring within the watershed(s) that have been identified as contributing to WREs. Natural disturbances such as fire and flooding also need to be identified.

A seventh step is to identify proposed management actions, including mitigation. This includes identifying all activities that are part of the proposed management action (e.g., miles of road to be constructed, silvicultural treatments, construction of a mine tailing pond); and all mitigation measures that will be implemented during the activity.

The next step is to identify reasonably foreseeable future management actions. This includes identifying all the activities that may contribute to the WREs which may occur within the foreseeable future. In addition, all mitigation measures to reduce nonpoint source pollution that might be used during these activities need to be identified.

And lastly, evaluate the WREs. This involves analyzing data to define: (1) Natural Conditions of the watershed in its natural state. Natural conditions are identified either by using actual data or a model that would estimate natural conditions from data for a watershed with comparable geomorphic features; (2) Existing Conditions can be defined by the natural condition when no land management activities have occurred within the drainage basin. When land management activities have occurred, existing conditions would be determined documenting how natural conditions have changed due to the additive effects of land management activities to result in the existing condition; (3) Project Effects evaluate direct and indirect effects of implementing only the proposed action and alternatives to it on the water resource; and (4) Effects to the Resource from Foreseeable Activities estimate additive effects of all past, current, proposed, and reasonably foreseeable land management activities within the hydrologic analysis area (regardless of land ownership) to determine cumulative effects on the water resources.

Hydrologists generally evaluate the potential water resource response to land management activity by subdividing the resource into the following three categories: (1) Streamflow Regime, (2) Water Quality, and (3) Stream Channel Morphology. Groundwater (movement and quality of water in the ground) is also an important part of the water resource. Currently, tools for analysis of potential impacts to ground water are not readily available. Except for mining, WREs analysis for other land management activities generally would not include evaluating ground water because the potential water resource responses are those that affect stream channel morphology and surface water quality not groundwater.

Streamflow Regime

This is discharge which occurs in natural channels. Streamflow is the result of water yielded from the drainage basin that appears in the stream. Water Yield is inputs (precipitation) minus losses (evapotranspiration, deep seepage, etc.) plus or minus changes in storage (i.e., depressions, impoundments and direct diversion). (Note that discharge is the rate of flow, or volume of water flowing in a stream at a given place and within a given period of time.)

Water Quality

This category deals with the physical, chemical, and biological characteristics of the water. Water quality is a function of sedimentation, solutes, temperature, pathogens, and streamflow. It evaluates the ability of the water to support a beneficial use (i.e., fish, recreation, water supply).

Stream Morphology

This category focuses on channel form. Channel form at any location is a function of streamflow, quantity and character of the sediment moving through the location, and character or composition of the materials making up the bed and banks of the channel. There are eight observable stream channel features which can be used to characterize these three factors: discharge, width, depth, mean flow velocity, sediment load and size, water surface slope, and roughness of the channel materials. A change in any one of these variables sets up a series of concurrent changes in the others, resulting in altered stream channel forms.

Stream channel morphology is the ultimate integrator of hillslope and stream channel responses (upland erosion, runoff, and large organic debris inputs) to land management activities within a drainage basin. Therefore, it is a primary indicator of WREs. (Note that large organic debris is discussed as a sub-category of this category. Streamflow regime and sediment are discussed separately later on.)

A stream channel has an upper level of tolerance to changes in the geomorphic processes. Channel aggradation or incision, stream bank undercutting, and increasing rates of mass wasting are indicator of exceeding a geomorphic threshold. For a selected hydrologic event, the risk of upsetting geomorphic equilibrium and initiating adverse WRE is greatly increased as the watershed disturbance approaches the upper level of tolerance.

Large woody debris in an important influence on stream channel stability. While it is important in creating structural diversity in stream systems (also important for aquatic and riparian habitats), depending on its location within a stream channel it may cause streambank erosion and local instability.

MERGING WATER RESOURCE INFORMATION INTO NEPA DOCUMENTS

Once watershed and stream channel morphology information has been gathered for a project, the hydrologist writes a hydrologic report documenting the information relative the proposed project. It is recommended that the report follows the NEPA document outline so that the interdisciplinary team (IDT) leader can more readily merge it into the NEPA document. The information included in the report should be commensurate with the importance of the issues and potential impacts. Oftentimes reports are written that cover items which are irrelevant to either of these items. The report might be likened to a novel, but a Michener novel is unnecessary. The report should be succinct and to the point. Additionally, the general public should be able to understand the terminology used in the report. (Sample reports may be obtained from the author.)

Chapter 1, Alternatives Including the Proposed Action

Three items are covered in this chapter which will require direct input from the hydrologist: issue identification; features common to all alternatives and specific to each alternative; and a comparison, by issue, the differences between alternatives.

If water is a "major" environmental issue, then hydrologists would be involved in the alternative development process. This would entail working with the IDT in looking at possible actions that when combined would address the water issue to various degrees. I will not go into this aspect of hydrologic input to the process.

"Issue Identification" is where environmental and managerial issues from scoping are identified. The statement of the issue should be reflective of what the real issue is not an individual hydrologist's opinion of what the issue is. After stating what the issue is, there should be a short discussion the cause/effect relationship(s) of implementing the land management activity. In essence, this is identification of the potential effects of grazing, timber, mining, and road building activities on the water resource. By taking the time to identify the cause/effect relation ships, the indicators needed to address the issue should be very

should be very apparent. Table 2 and 3 provide an example of some of the potential effects of timber and road building activities on the water resource. As an example, using the information in both tables, potential effects of implementing an alternative for timber harvest and road construction might be evaluated using the indices: Water Quality as estimated percent sediment yield increase above natural condition for one decade; Streamflow Regime, as annual water yield increases above natural conditions for five decades and the natural, existing, and potential conditions to illustrate changes in peak flows; and Stream/channel Morphology, as miles of stream channel that would be out of equilibrium.

The "Features of the Action Alternatives" section discloses those features which are common to all of the action alternatives. The most common items discussed are mitigation measures and monitoring. The mitigation measures discussed most often are the Best Management Practices (BMP) which will be used to reduce, to the extent feasible, the potential impact during the implementation of the sale. The discussion generally covers timber sale contract C provisions or Road Specs that will be used. Depending on the number of mitigation measures that will be used, the discussing either in this section or is an appendix to the NEPA document.

Care must be taken on how watershed rehabilitation work is included as mitigation is discussed. If the watershed rehabilitation is not being undertaken to reduce the potential impacts of implementing any of the action alternatives do not include it in this section. If, on the other hand, it is being undertaken to reduce the potential impacts of the project then do disclose it here. The reason for this point of clarification is that watershed rehabilitation identified as part of all of the action alternatives is mandatory to carry out. Watershed rehabilitation work which is ongoing and not part of the proposal is just something that is occurring. The potential effects of the ongoing rehabilitation work must be disclosed in the environmental effects chapter.

One further word of caution is the need to clearly document the effectiveness of all the mitigation measures being proposed for implementation. The legal foundation for this is contained in the 9th Circuit Court of Appeals 1985 brief, Northwest Indian Cemetery Protective Association, et al., vs. Peterson, et al. Summarizing, the court said that a mere listing of mitigation measures is not enough. There must be documentation of their effectiveness.

If monitoring, specific to the proposal, will be undertaken then the specifics of that monitoring must be disclosed here. Reference can be made to the

Table 2. Land management activity and potential water resource response: Timber Harvest.

Action	Resource at issue	Potential response
All timber harvesting activities	Stream channel morphology	Changes in streamflow regime or sediment concentration in the water may cause:
		Channel aggradation or degradation resulting in a change in width/depth ratio. Shift in the dominant streambed particle-size composition.
	Surface water quality	Water yield increases may occur due to a decrease in evapotranspiration.
		Peak flows may occur earlier in the year due to faster snowmelt rates.
	Stream flow regime	On-site soil erosion may occur if soils are compacted or disturbed during harvesting. When soil is delivered to stream channel there may be an increase in sediment concentration. Depending on streamflow conditions, the shift in sediment concentration may lead to a change in sediment storage transport and may result in increase of fine sediment particles in the streambed.
		An increase in stream temperature can occur if streamside vegetation is removed, especially along south and southeast edges of perennial streams. (Intermittent streams are not considered too strongly because they usually contribute runoff during snow melt when stream temperatures are cold.)

Table 3. Land management activity and potential water resource response: Roads.

Action	Resource at issue	Potential response
Stream crossings (bridge/culvert placement)	Surface water quality	Exposed soils immediately next to streams generally result in increased sediment delivery to streams.
	Surface water quantity	Localized increases in water velocities may occur if the channel is narrowed and straightened at the crossing producing scour channel immediately downstream.
Construction	Surface water quality	Increased sediment delivery to streams depending on how much soil is exposed on cut-slopes, road prism and fill-slopes during construction.
	Surface water quantity	Water yield increases can occur from construction just as they do from timber harvest, but they are more permanent if the road is permanent.
		Water velocities usually increase when a channel is straightened. The increased velocities tend to scour a new channel, particularly since vegetation is removed.
Reconstruction	Surface water quality	Increased sediment concentration may occur depending on how much soil is exposed on cut-slopes, road prism, and fill-slopes during reconstruction.
Temporary roads road	Surface water quality/quantity	Sedimentation; stream channel changes; mass soil/geologic movement.
Existing road stabilization	Surface Water quality	Increased sediment concentration may occur depending on how much soil is exposed on cut-slopes, road prism, and fill-slopes during stabilization.
Maintenance	Surface water quality	Increased sediment concentration.

monitoring and the details of the monitoring program can be included in an appendix to the NEPA document. Be very cautious about simply stating the monitoring that will be done is covered in the Forest Plan. If this statement is made for every project, then you are in essence stating that every item called for in the Forest Plan monitoring chapter will be accomplished for all projects. In most cases this is not what will be done. If monitoring being done elsewhere is reflective of the potential impacts of implementing any of the action alternatives, state that here and why the data is applicable.

If there is alternative specific mitigation or monitoring, it would be disclosed in the "Features of Each Action Alternative" section. Keep in mind that the items that are specific to an alternative should only relate to that alternative and no other alternative.

The "Comparison of Alternatives" section is a Reader's Digest condensed version of the information disclosed in the environmental consequences section. There is generally a short narrative explaining the potential effects of implementing each alternative. Often times at the end of this information there is a "final" comparison of the differences between alternatives and trade-offs presented in a comparison matrix.

Chapter 2, Affected Environment

The information herein forms the basis for the disclosure of environmental consequences. The issues related to the proposed action provide the focus of the water resource discussion. All too often, items are discussed in the "Affected Environment" section of the document but never heard about in the "Environmental Consequences" section. It is critical to make sure to track the indices of measurement identified throughout through the "Environmental Consequences" section. It must be noted, though, that even when hydrology is not a driving issue, there may be a minimum amount of information that should be presented in order to evaluate the management situation, capability, and special conditions or situations which involve hazards that may cause impacts to the

water resource. The information to be presented would be dependent upon the cause/effect relationship of the proposal being evaluated.

"Analysis Area." Section identifies the watersheds included in the WREs analysis. Since the main stream channel of a drainage basin reflects the integrated effects of all natural process land activities, The WREs analysis must be made for an entire drainage basin. The rationale for the selection of the analysis area boundary must be clearly disclosed. "Tools Used in the Analysis." Evaluating WREs is not a precise science; it is a young and developing field. No one technical tool will reasonably simulate all variables for all ecologic and geomorphic systems. Adding to the complexity of the situation are limitations in full understanding of geomorphic processes in mountainous terrain, and influences of climate and human activities on process rate and resulting impacts to down stream beneficial uses of water. Table 4 lists some of the analysis tools being used in the Northern Region to help assess WREs. "Data Collection and Analysis." Tools selected for use in analysis will dictate the data that is to be collected. As to data collection: if there is data relevant to the project that has been collected specify what it is? In most cases this would be streamflow, sediment, macroinvertebrates, temperature, channel stability, stream type mapping, and the like. Specify how many years the data have been collected, what time of year, and so forth. If the field data were sent to a lab for analysis, identify who the lab and what specific test was done on it. If the analysis was internal state this. (Note that this information does not necessarily need to be included in the NEPA document. It must be in the project file though.)

"Past Management." This section identifies all of the management activities that have occurred in the analysis area that are contributing effects to the water resource. Management activities include but are not limited to timber harvest, road construction, grazing, mining, and recreation.

"Water Uses." Both uses related to water rights and water quality are identified. For water rights, identify both consumptive and nonconsumptive uses of water. For water quality, identify the designated beneficial uses of the water as specified in the State

Table 4. Summary of analytical tools used in the Northern Region.

Issue	Analytical tool	How to address issue
Effects on stream channel morphology	Rosgen stream classification with R-1 channel stability rating	Provides information on stream channel form stability and dominant streambed particle size.
	COWFISH	Provides information on streambank degradation from grazing.
	Photos	Provides a visual verification of past and existing channel geometry and streambed composition.
Potential changes to streamflow regime	R1WATSED/Forest plan water yield models; SCS models; WET	Quantifies estimates of natural, existing, and "disturbed" land water yields
Potential loss of LOD recruitment	Stream surveys	Quantifies existing LOD percentage within streams
	PROGNOSIS	Predicts stand growth, thus gives an indication of LOD that might be available for future recruitment.
Potential change in sediment concentration	R1WATSED	Quantifies estimates of natural, existing, and "disturbed" l and sediment yields. Incorporates on-site erosion and soil delivery factors to channels.
Potential change in temperature	Brown's Temperature Model	Quantifies estimates of natural stream temperatures and changes in temperature resulting from land management activities.

water quality standards. Identifying these uses provides an understanding of what uses might be potentially impacted.

Evaluating WREs in watersheds of mixed ownership may present a difficult and complex management situation. Often, actions of non-Forest Service landowners are unknown so scheduling land use activities on National Forest System lands to minimize the risk of incurring adverse WREs is uncertain.

If actual data are available then they should be the basis of the discussion. Do not "eliminate" use of the data and go straight to a model. Additionally, knowing that you will be using a model to help predict existing conditions and the effects of implementing the alternatives, the model output needs to be compared to the real data to calibrate/validate the model.

When a model is used to identify the natural, existing conditions, and project and cumulative effects, a discussion of the model used and assumptions associated with it needs to be discussed. Be able to "justify and defend" the selection of the model.

If best professional judgment is used as the tool, supporting documentation of the rational behind it must be documented. Use of best professional judgment as a tool occurs only when the judgment is supported by current literature, research, and opinions by other experts. It is not acceptable to present unsupported, arbitrary, and personal value judgments.

In writing the "Water Quality" section, stick to facts. Do not include statements such as the waters in the area are "pristine." You must have data to back up that statement. If you do not have data then do not be presumptuous in assuming that the world is pristine.

Since designated beneficial uses are the bottom line for water quality, it is recommended that the initial discussion would be the state water quality criteria established to protect the designated beneficial uses (identified earlier). The selection of parameters to discuss will depend upon the proposed activity. For example, for mining it will be more critical to include a discussion on the chemical parameters that will be affected by the mine. It must be noted that for most states that the criteria for sediment is narrative therefore, a direct comparison to a numerical criteria is not possible.

Although, there are no State water quality standards for macroinvertebrates, Forests collecting this information should present it. There is a growing trend towards using macroinvertebrates as one of the parameters to assess stream health.

For timber sales, placer mining, and grazing, sediment is going to be the parameter which we will primarily be dealing with. Sediment is derived primarily from erosion of the watershed and channel cutting. All watersheds produce sediment, for erosion is a natural geologic phenomenon. There are three basic types of erosion: Surface, or detachment and removal of individual soil particles form the land surface; Mass Movement, such as landslides and slumps; and Channel Cutting, or the detachment and movement of material from a stream channel (this includes both the shifting of bed materials or material from bank collapse).

Information should be provided on the natural and existing sediment concentrations in water, by stream systems, with specific reference to known sediment sources. The discussion should provide an understanding of sediment storage/transport in a stream channel as related to streamflow characteristics, and should explain how past/existing activities in the analysis area have interacted with the major geomorphic process within the watershed. (This will help in determining the effects of the proposed action in the next section.)

The derivation of sediment "amounts" involves evaluation of; (1) erosion or mass-failure that may be generated from a hillslope or in-channel for example, (2) the quantity and timing of on sediment delivery to a stream channels from a specific land unit, and (3) sediment transport within the stream system at the mouth of the drainage basin.

The natural erosion rates, sediment delivery to streams and sediment transport are developed through use of actual data, extrapolation of data from a similar (in geomorphic characteristics) drainage basin, or a model to derive these factors. Existing conditions are derived in the same manner but taking into account any activities that have occurred within the analysis area.

Temperature is usually the secondary physical water quality parameter of concern. Information should be provided on the general stream temperatures (maximum, minimum, and yearly changes), by

stream systems, with specific reference to known temperature sensitive streams. The discussion should provide an understanding of temperatures as related to the designated beneficial uses of water. If there are known temperature sensitive stream segments within the analysis area, then it would be recommended to include a map of the stream system and location of the sensitive segments. This will facilitate proper delineation of stream course protection needs in the timber sale contract C provisions.

The natural stream temperature is developed through use of actual data, extrapolation of data from a hydrologically similar drainage basin, or a model. Existing conditions would be derived in the same manner but taking into account any activities that have occurred within the analysis area.

Depending on the potential impacts, the "Streamflow Regime" discussion may relate to the overall timing of streamflow (hydrograph characteristics, peak flows, flood flows). If the project has a bearing on water availability (water use and demand) then discussion would center on total streamflow volume (annual water yield, seasonal water yield). Discuss any unique climatic effects on water yield as well.

A natural streamflow regime is developed through use of actual stream flow data, extrapolation of data from a similar drainage basin, or a water yield model to derive streamflow. Existing conditions are derived in the same manner but taking into account any activities that have occurred with in the analysis area.

The "Drainage Basin Description" section summarizes the overall drainage basin characteristics and how the watershed functions. Items covered include, but are not be limited to geology, landforms, and the main geomorphic processes that contribute to water resource effects (i.e., mass failure, in-channel erosion, natural erosion rates). The magnitude and frequency of any "events" should be discussed. This sets the foundation for understanding how the proposed activities may interact with the watershed processes.

The "Stream Channel Morphology" section provides a discussion of the stream channel geomorphology. Such items as stream gradients, stream bank control (alluvium vs. bedrock, and where sets up channel scour potential), channel entrenchment, substrate, and so forth. Discuss whether the stream channels are in "equilibrium" between sediment and stream discharge (energy) capabilities (i.e., Are the streams energy/sediment limited? Is the channel in "equilibrium"? Is active down cutting taking place?) An example statement would say, "streams are low gradient, wide streams have become energy limited because of the persistent input of sediment that has remained in the stream system. As a result, stream channel aggradation is occurring in the low gradient stream channels. Additionally, there has been a shift in dominant streambed particle size composition from cobbles to sands and gravels."

In order to derive the natural channel morphology, the hydrologist evaluates the potential impacts that past activities, within the drainage basin, may have had on the stream channel with respect to its "equilibrium." This is done predominantly based on the hydrologist's professional judgment based on items such as photos, and stream channel conditions in an undisturbed drainage basin of like physical characteristics.

Existing stream channel configuration, stability, and streambed particle size composition are obtained through channel types (Rosgen 1985), physical channel cross-section measurements, channel stability evaluations (Pfankuch 1978), and visual observations of the streambed substrate and large organic debris volume/location. This provides an understanding of the channels existing "equilibrium" between sediment and discharge. It is recommended that a map with both stream types and stream segments not in equilibrium be included in the NEPA document.

Additionally, information should be provided on Large Organic Debris (LOD) volumes in channels, general loading rates, the role it plays in channel stability and if known, how much sediment LOD retains compared to total sediment movement. Identify if LOD is important in maintaining channel structure.

In order to derive the natural LOD loading and stability, the hydrologist evaluates the potential impacts that past activities, within the drainage basin, may have had on the these factors. This is done predominantly and using the hydrologist's professional judgment based on items such as photos, and LOD in an undisturbed drainage basin of like physical characteristics.

Existing stream large organic debris (LOD) volume, "supply" rates, and location are obtained through physical channel cross-section measure-

ments, channel stability evaluations (Pfankuch 1978), and visual observations of the LOD volume/location.

The last suggested item to be discussed is "Regulatory Framework" related to water quality. In Region 1, for example, this will relate to the use of BMPs to reduce nonpoint source pollution to meet the intent of both the State of Idaho and Montana water quality standards.

The other area that may require coverage is wetlands. If wetlands are present within the project area then a discussion relating to the Corps of Engineers requirements at 33 CFR 323.4 is needed in this section as well. It must be remembered that the silvicultural exemption is for tree removal only. Road construction associated with harvesting must be in compliance with the BMP requirements in this section as well.

Chapter 3, Environmental Consequences

This section is not where a simple listing of number changes occurs. This is crux of the document where the potential impacts on the resource, as a result of implementing any of the alternatives, are disclosed. A mere listing of only number changes does not provide the "so what" needed to demonstrate whether or not there are impacts. All to often, this is what has been included in this section. We need to go the step further to state the "so what". Referring back to Table 1, the first item identified was the designated beneficial uses. Therefore, an "interpretation" is needed as to whether or not a designated beneficial use will be supported or not (this needs to be done in concert with the fisheries biologists).

Some general criteria for overall contents of this section are: (1) develop quantitative estimates where possible, (2) compare the estimated effects to predetermined standards and to criteria linked to existing legal requirements for water resource protection, (3) use established techniques and methods to estimate effects, (4) be able to "justify and defend" the estimation of the effects.

At the beginning of the environmental consequences section there is usually a discussion on the cause/effect relationships. This discussion should link to the issues and indices of measurement identified earlier (and vice versa). The NEPA document also includes discussions on the direct, indirect, and cumulative effects of implementing the proposed action or an alternative to it.

Direct effects are those caused by the action and occur at the same time and place. The most common direct effect on the water resource occurs during road construction. When a culvert or bridge is installed, sediment may be directly introduced into the stream channel.

Indirect effects are caused by the action and are later in time or farther removed in dsitance. The most common indirect water resource effects are potential changes in streamflow regime, sediment concentrations in streams, and stream channel geomorphology.

Cumulative effects result from incremental effects of proposed actions when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or other) or person undertakes such actions. The most common cumulative water resource effects are changes in streamflow regime, sediment concentrations in streams, and stream channel geomorphology.

The cumulative effects discussion is a very crucial section of NEPA. Effects need to encompass all land management activities which may occur from Federal, State, and private lands within the drainage basin. Therefore, it is highly recommended that a short recap of actions considered in cumulative effects be given at the start of the discussion. If there are no other activities planned within the analysis area, say so and also that cumulative effects would be the same as indirect effects of implementing the alternative.

One other point—evaluating the effects of grazing has often been brushed aside by stating either that effects are baseline or involve control of cattle in riparian areas, and will be addressed further in the allotment management plan. This is insufficient reasoning for not addressing cumulative effects of grazing with the proposed activity. Continued grazing along streambanks will continue to exacerbate channel degradation. Hydrologists must use their knowledge about how the steam system is functioning and combined with the indirect effects of both grazing and the proposed action to make an interpretation of what will happen to stream channel morphology. (The same idea would be true of placer mining.)

DISCUSSION POINTS ON WATER RESOURCE CATEGORY

Water Quantity

Information should be provided on the potential change of water yield timing (shift in hydrograph), flood occurrence or instantaneous peak flow volumes by stream systems. Discussions should provide an understanding of how the predicted shift in the streamflow regime will affect its sediment storage/transport in the streams. Potential direct changes to the existing streamflow regime are generally derived through the use of a water yield model. The model estimates levels of change in streamflow. The indirect effects to the water resource are discussed in terms of the effects estimated changes in streamflow may have on channel morphology.

Cumulative effects are generally derived by modelling estimated additive effects to cumulative effects to water yield from all past, present, and projecting any reasonably foreseeable future actions in the drainage basin should be estimated. Interpreting potential indirect changes to the water resource, as a result of these activities, relates to potential effects on channel morphology.

Water Quality and Sediment

Sediment information should be provided on potential change of sediment delivery to the stream channel, concentration in the water, by stream systems, with specific reference to any specific sediment sources. The discussion should provide an understanding of how the predicted shift in the sediment concentrations will affect its storage/transport in relation to streamflow characteristics.

Potential direct changes to the existing sediment regime are generally derived through the use of a sediment model. The model results are predicted levels of on-site erosion and change in sediment delivery to channels. Indirect effects to the water resource are discussed in terms of the additive effects any changes in sediment amount and "particle size" shifts may have on channel morphology.

Cumulative effects are generally derived by modelling estimated additive effects to sediment yield. Transport in channels from all past, present, and projecting any reasonably foreseeable future actions within the drainage basin. The procedure for interpreting potential cumulative effects to the water resource, as a result of these activities, is related to potential changes in channel morphology.

Temperature information should be provided on the shifts in general stream temperatures, by stream systems, as a result of the proposed activity. Discussion should provide an understanding of how this shift in stream temperature may affect designated beneficial uses of water.

Potential direct changes to the existing stream temperature are generally derived through the use of a stream temperature model. The direct effects are predicted levels of change in stream temperature in specific stream reaches. The indirect effects to stream temperature are discussed in terms of the project effects on stream temperature changes downstream. Cumulative effects on stream temperature are generally derived by modelling estimated additive effects to cumulative effects of temperatures from all past, present, and projecting any reasonably foreseeable future actions in the watershed.

Discuss the potential for shifts in channel "equilibrium" and resultant channel cross-section changes that might occur. This is a result of interpreting the effects on both the streamflow and sediment regimes; and large organic debris supply. Potential changes to stream channel morphology from the project's indirect effects as well as effects of cumulative actions are identified by relating the existing stream channel conditions with regard to the sediment-stream discharge "equilibrium" continuum with any direct impacts that may occur to streamflow and sediment regimes. Consideration also needs to be given to any potential shifts in large organic debris supply that may occur. Based on this, best professional judgment is used to interpret if aggradation or degradation will occur in the channel resulting in a channel type shift.

Potential changes to LOD recruitment are identified by relating the existing LOD recruitment and locations with any direct impacts that may occur to streamflow and sediment regimes. Consideration is given to any potential shifts in large organic debris supply that may occur. Based on this, best professional judgment is used to interpret if aggradation or degradation will occur in the channel and result in a channel type shift.

Information should be presented on what levels of riparian area harvesting will occur and the resulting sifts in LOD loading. If there will be a shift in LOD what

effect will the shift have on channel stability-sediment movement and channel structure. The effects should be described in terms of direct impacts to adjacent stream channel and indirect effects of sediment or discharge changes to the downstream channel stability.

"User Notes on Cumulative Effects" is a very crucial section of the NEPA document. A very clear statement of the cumulative effects must be presented. Remember that the Council on Environmental Quality regulations require a hard look at past, present, and reasonably foreseeable effects. The effects need to encompass all that may occur from both federal, state, and private lands.

It is highly recommended (based on evidence working with appeals on this topic) that a short recap of the actions considered in cumulative effects be given at the start of the discussion. If there are no other activities planned within the analysis area state so and that the cumulative effects would be the same as indirect effects of implementing the alternative. One other point, evaluating the effects of grazing have often time been brushed aside by stating either that the effects are baseline or control of cattle in the riparian area will be addressed in the allotment management plan. These are not valid reasons for not addressing the cumulative effects of grazing with the proposed activity. Continued grazing along streambanks will continue to exacerbate channel degradation. Hydrologist must use their knowledge about how the stream system is functioning, and combined with the indirect effects of both grazing and the proposed action, make an interpretation on what will happen to stream channel morphology. (Note that the same idea would be true of placer mining.)

In the section, "Possible Conflicts with Plans and Policies of Other Jurisdictions," there would be a discussion on how State water quality standards would/would not be met. Additionally, if there are wetlands in the project area, a discussion on the Corps of Engineers 404 Regulatory Program is needed. The regulatory requirements can be found in 33 CFR 323.4(a)(2). In addition, any road construction must be constructed and maintained pursuant to 33 CFR 323.4(a)(f and 6).

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Coastal Zone Management Act - A Forestry Perspective

Michael J. Phillips[1]

Abstract.--The role of the Coastal Zone Management Act of 1972, as amended in 1990, in the control of silvicultural nonpoint source pollution is discussed. This purpose of Section 6217, added in 1990, was to develop and implement management measures for nonpoint source pollution by working in close conjunction with state and local authorities. The involvement of state forestry agencies with the Environmental Protection Agency (EPA) has become a positive process for state forestry agencies to provide critical input to the EPA. This process has aided the development of realistic, practical, and effective solutions to nonpoint source pollution issues.

BACKGROUND

The past two decades have been productive and busy years in federal and state efforts to maintain, protect and enhance the water resources of the United States. Control and abatement of water pollution has been a national priority since passage of the landmark Federal Water Pollution Control (FWPC) Act of 1972 (PL 92-500). This Act was an ambitious piece of legislation with a declared objective to "restore and maintain the chemical, physical, and biological integrity of the nation's waters." It envisioned zero discharge to the nation's water bodies by 1985 and to attain, where possible, waters considered "fishable and swimmable" by 1983.

Since the passage of the FWPC Act of 1972, tens of billions of dollars have been spent on technology and regulation to control traditional "point sources" of pollution. Successful efforts in the cleanup of point sources has resulted in a shift in the focus for water quality protection. According to state water quality assessments, nonpoint source (NPS) pollution is now identified as the primary single factor preventing the attainment of water quality standards nationwide. However, compared to the resources committed to reducing point source pollution, the level of funding to address the complex issue of NPS pollution is likely to be much reduced.

As part of the overall strategy to protect natural resources, Congress enacted the Coastal Zone Management Act (CZMA) of 1972. Although water quality is not specifically identified as a policy of the Act, it was central to achieving the programs goals. CZMA established a national program for states and territories to voluntarily protect and manage coastal resources. Federal approval and grant funding for program implementation were contingent upon states demonstrating an ability to: 1) regulate land and water use, 2) regulate coastal development, 3) resolve conflicts among competing uses, and 4) implement enforceable policies to carry out coastal programs.

States and territories which border an ocean, the Great Lakes or the Gulf of Mexico are eligible to participate in the program under the authority CZM Act of 1972. Twenty-nine of 35 eligible states have approved CZM programs. Six states are in the process of developing programs or have elected not to participate. Approved coastal programs provide protection to wetlands, estuaries, beaches, dunes, coral reefs, and fish and wildlife habitat. Resource protection is accomplished by state laws, regulations, permits, and planning and zoning ordinances.

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1990 AMENDMENTS TO THE CZMA

The Costal Zone Act Reauthorization Amendments of 1990 (PL 101-508) amended the CZMA of 1972 to include a new section (Section 6217) on controlling nonpoint source pollution in coastal areas. The Amendments recognize that coastal areas constitute a unique resource requiring protection. Under Section 6217, all states with federally approved CZM programs are required to develop a coastal NPS control program. As envisioned by the Environmental Protection Agency (EPA), these programs are not intended to replace existing CZM or state NPS programs. They are intended to update existing programs and integrate them more closely with CZM programs, and with other federal and state water quality activities.

The purpose of the program under Section 6217 is "to develop and implement management measures for nonpoint source pollution to restore and protect coastal waters working in close conjunction with other state and local authorities." EPA has the responsibility to develop management measures guidance while the National Oceanic and Atmospheric Administration (NOAA) has the principal responsibility to develop program implementation guidance.

Management measures emphasize pollution prevention by reducing NPS pollution at the source. They are technology based rather than water quality based. Management measures are defined as "economically achievable measures for the control of the addition of pollutants from existing and new categories and classes of nonpoint sources of pollution, which reflect the greatest degree of pollutant reduction available through the application of best available nonpoint source pollution control practices, technologies, processes, siting criteria, operating methods, or other alternatives." Management measures are generally described in terms of management systems or combinations of individual practices that collectively control the targeted pollutant.

As currently proposed, the management measures guidance specifies measures to control NPS pollution from agriculture, silviculture, urban, hydromodification, and marinas. It also specifies management measures (e.g. wetlands, riparian areas, vegetative filter strips) that apply across land uses. State coastal programs are required to be in conformity with EPAs management measures although states have the option to employ a range of management practices if they can demonstrate that these practices are equal to or superior to the effectiveness of the guidance management measures. The state nonpoint programs must also include enforceable policies and mechanisms to implement the guidance management measures. Enforceable policies and mechanisms include traditional regulatory controls and nontraditional approaches such as incentives programs.

STATE RESPONSES

In developing the proposed management measures guidance, EPA adopted a work group approach to draw upon expertise outside the agency. The state forestry agencies were actively involved in the workgroup process. The workgroup approach was endorsed by the National Association of State Foresters since many of the state's forestry organizations have been delegated the major responsibility for controlling silvicultural NPS pollution within their states. The state forestry agencies agree on the need to ensure comprehensive and effective NPS control programs. Working relationships and partnerships are critical if national mandates are to become state programs that are practical, effective and implementable.

When the initial draft management measures guidance document was published, the state forestry organizations were concerned that national standards were being proposed that would bring too great a degree of specificity to the enormous range of physiographic diversity across the United States. There was concern that the management measures could not be meaningfully applied to most of the forested regions of the United States.

The state forestry organizations were also concerned that the effect of the coastal NPS control programs would be to supplant existing programs. Since at least 1987, the states have expended major efforts nationwide to develop and implement NPS control programs under guidance of Sections 208 and 319 of the CWA. Most state forestry organizations prefer to continue the 319 approach that delegates the authority to the states to develop and implement management programs that are responsive to local needs and conditions. In the view of many of the state foresters, water quality problems that are presently attributed to silvicultural activities are not due to the ineffectiveness of the preventative practices, but to

the failure to implement them properly. What is needed is not a new program or direction, but the time and resources to ensure broad implementation of best management practices under the guidance of the 319 program. Additional measures or programs should compliment and blend with, rather than duplicate or conflict with existing state programs that are meeting the water quality goals of the state.

The willingness of EPA to include the state forestry agencies in the review and development of the management measures guidance document has been beneficial to the interests of both organizations. From the perspective of the state forestry agencies, the current version of the management measures guidance document is much improved and reflects the discussions and recommendations of the workgroup. The distinction between what constitutes a required management measure and a suggested management practice has been clarified and will now provide meaningful guidance to the states as they develop their coastal NPS control programs.

However, there are several remaining issues that the states are concerned about in regards to the management measures guidance document. The primary concern is the inference that a pre-harvest plan will be required as part of the management measures. The concept of pre-harvest planning has been expanded to include notification of the appropriate state agency prior to the implementation of the pre-harvest plan. The state forestry agencies support harvest planning as a necessary component of forest management activities, but not mandated forest harvest plans as a national requirement. Notification of this to the appropriate state agency implies that state forestry agencies will be provided with a major new oversight responsibility. Many state forestry agencies are undergoing significant budget and personnel reductions. Formalized review of timber harvest plans would become another bureaucratic workload task for which many states would not have the resources to carry out in a timely and cost-effective manner.

Another major concern is the cumulative effects considerations identified in the management measures and referenced in the management practices. The technologies and capabilities of state organizations are not sufficient to undertake cumulative effects analysis. It is an analysis that works best in forested watersheds with a single land use. State, county, federal and private forests are often in mixed ownership and land use watersheds where cumulative effects analysis would be complex and difficult.

The recommendations on cumulative effects in the guidance document are only applied to forestry. If cumulative effects analysis is to be required for forestry, it should be just as important to apply this analysis to other land uses. Forestry is generally considered to be less than five percent of the NPS problem nationwide. To have any utility as an analytical tool, cumulative effects has to consider the other 95 percent of the problem. In mixed watersheds in particular, it is meaningless to only account for the impacts attributable to forestry.

From a state forestry perspective, cumulative effects could be dealt with in two ways. Rather than as part of a management measure, cumulative effects could be addressed under the management practices section as a planning tool. The other option would be to delete references to cumulative effects under the forestry management measures and prescribe it as a separate chapter in the guidance document applicable to all land uses.

CONCLUSION

The involvement of the state forestry agencies with EPA throughout the workgroup process has been very positive. EPA has given forestry the opportunity to provide critical input in finalizing the forestry chapter of the management measures guidance document. The process of involving state agencies in workgroups provides EPA with additional opportunities to develop realistic, practical and effective solutions to complex resource issues. It would be in the best interests of the state forestry agencies and EPA to expand this process to address future resource issues.

Above-Below Diversion Study

Lela Chavez[1]

Abstract.--Stream channel conditions were studied above and below diversion sites on 20 streams in Colorado. Ninety-one percent of the channel reaches showed a decrease in bankfull cross sectional area, below diversions. Eighty-five percent sustained a decrease in bankfull width, and eighty-eight percent had decreased in mean depth at bankfull. D50 particle sizes of streambed material decreased in seventy-two percent of the reaches.

INTRODUCTION

Beginning in 1988 and continuing in 1989, the Forest Service studied stream channel conditions above and below streamflow diversion sites at twenty streams in Colorado. The reason for the study was to document the changes that occur in a channel as a result of reducing and in some cases eliminating the flows. One of the major bases for the instream flow claims filed by the Forest Service in Colorado is that river channels are for the most part self-formed by the water and sediment they receive and carry, that an equilibrium has been reached between the stream and its surrounding watershed, and that any disruption in watershed conditions will lead to a response by the stream.

Leopold and Langbein (1962) showed that rivers form and maintain their own channels. The operation and behavior of a natural stream and the characteristics of its channel, the velocity of flow, width, depth, channel patterns, sinuosity, and slope are adjusted over a period of time so that the sediment supplied to that channel is transported downstream with the available discharge. Such streams are said to be in quasi-equilibrium. The size, shape and form of a stream channel reflect the size of the watershed area and the amount of precipitation which falls in the drainage basin, and is intimately related to the amount of water and sediment coming from the basin upstream.

Above-below diversion studies can indicate if watershed conditions are disrupted by diverting some or all of the flow from the streams in the watershed, causing streams to adjust geomorphically. Thus, the capacity of a stream to carry water will be diminished by the continuing supply of sediment from the watershed and by the encroachment of vegetation from the banks until, ultimately, absent bypass flows, no channel will remain.

STUDY PROCEDURES

The primary criteria that were used in selecting a diversion site for the study were:

1. The diversion had been in existence and diverting water for a number of years.
2. The site was reasonably accessible to survey crews.
3. The sites showed a range of channel conditions representative of the channels found in the South Platte River Basin. This is the river basin in which the channel maintenance flow litigation was occurring.

Cross sections were located above and below the diversion. The channel reaches were selected based on similar channel characteristics and at locations where the channels were adjustable. Locations where channel width was affected by debris jams, large rocks, etc. were avoided if possible. The conditions above and below the diversion structure such as slope, terrain, sinuosity, stream type, etc. were reasonably comparable in all respects except for the reduction in flow (Table 1).

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Table 1. Cross-section data, 20 stream reaches in Colorado.

1988 Cross Section Number	Stream / Diversion Name or ID	Xsec Location Abv-Bel Diversion	Reach or Channel Form	Stream Type	Reach Gradient %	Xsec Bankfull Width Ft	% Change	Bankfull Xsec Area Sq Ft	% Change	Mean Depth at Bankfull Ft	% Change	Pebble Count Bed D84 mm	Pebble Count Bed D50 mm
01	FRASER River @ DWD Diversion	Above	Straight	B2	2.00	26.5	-33	45.07	-58	1.70	-38	82	43
07		Below	Straight	B2	1.00	17.8		18.68		1.05		140	60
02	FRASER River @ DWD Diversion	Above	Meander	B2	1.30	32.20	-69	28.86	-59	.89	+34	11.5	6.2
08		Below	Meander	B2	.60	9.89		11.81		1.19		56.0	11.0
06	FRASER River @ DWD Diversion	Above	Straight	C1	1.20	27.25	-34	33.53	-47	1.23	-19	170	76
03		Below	Straight	C1	0.90	17.90		17.65		0.99		138	74
05	FRASER River @ DWD Diversion	Above	Meander	C1	1.60	33.30	-56	29.03	-45	0.87	+25	105	45
04		Below	Meander	C1	1.50	14.70		16.04		1.09		68	27
09	JIM CREEK @ DWD Diversion	Above	Straight	B3	3.50	13.90	+4	17.63	-51	1.27	-53	180	74
11		Below	Straight	B3	3.70	14.50		8.69		.60		165	76
10	JIM CREEK @ DWD Diversion	Above	Meander	B3	4.20	19.10	-16	28.65	-45	1.50	-35	250	102
12		Below	Meander	B3	3.30	16.00		15.63		.98		190	94
13	unt ELK CREEK @ DWD Diversion	Above	Straight	A2a	11.90	3.30	-12	1.81	-45	.55	-38	200	80
14		Below	Straight	A2	7.70	2.90		.99		.34		160	58
16	E.FK. ST. LOUIS CREEK @ DWD Diversion	Above	Straight	A2	8.40	9.20	-22	11.30	-62	1.23	-52	360	190
18		Below	Straight	A2	6.40	7.20		4.27		.59		380	165
15	E. FK.ST LOUIS CREEk @ DWD Diversion	Above	Meander	A2	8.40	7.30	-3	10.53	-50	1.44	-49	400	170
17		Below	Meander	A2	6.40	7.10		5.28		.74		310	145
20	STEELMAN CREEK @ DWD Diversion	Above	Straight	B2	2.30	11.80	+12	10.62	+4	.90	-8	135	52
21		Below	Straight	B2	2.40	13.20		11.01		.83		110	55
19	STEELMAN CREEK @ DWD Diversion	Above	Meander	B2	2.30	10.90	+5	16.80	-36	1.54	-39	250	80
22		Below	Meander	B2	2.40	11.40		10.71		.94		135	48
23	BENNETT GULCH	Above	Straight	A2	7.30	6.50	-54	3.42	-81	.53	-58	330	128
24		Below	Straight	A2	9.10	3.00		.65		.22		335	42
25	CHAPMAN GULCH	Above	Straight	A2	6.50	19.30	-8	15.50	+36	.80	+47	340	112
26		Below	Straight	A2	7.30	17.80		21.08		1.18		750	150
27	LOSTMAN CREEK	Above	Straight	C1	.70	14.33	-29	18.97	-66	1.32	-55	205	115
30		Below	Straight	C1-B2	1.70	10.10		6.40		.59		165	38
28	LOSTMAN CREEK	Above	Meander	C1	.70	19.70	-57	17.73	-78	.89	-48	280	148
29		Below	Meander	C1-B2	1.70	8.40		3.87		.46		190	53
38		Above	Meander	B2	1.80	17.30		17.30		1.00		265	115
37	LOSTMAN CREEK	Above	Straight	B2	1.80	14.60	-33	14.00	-76	.96	-65	300	120
39		Below	Straight	B2	2.50	9.70		3.33		.34		192	70
31	HALFMOON CREEK	Above	Straight	B2	2.10	29.30	+26	30.45	+33	1.04	+6	400	155
32		Below	Straight	B2	1.90	36.90		40.49		1.10		400	190
35	JEFFERSON CREEK	Above	Straight	B2	1.70	10.30	-32	13.90	-73	1.35	-60	180	64
33		Below	Straight	B2	1.70	7.00		3.79		.54		NA	NA
36	JEFFERSON CREEK	Above	Meander	B2	2.70	8.70	+6	11.83	-4	1.36	-10	NA	NA
34		Below	Meander	B2	1.70	9.26		11.29		1.22		NA	NA

Table 1. Cross-section data, 20 stream reaches in Colorado (continued).

1988 Cross Section Number	Stream / Diversion Name or ID	Xsec Location Abv-Bel Diversion	Reach or Channel Form	Stream Type	Reach Gradient %	Xsec Bankfull Width Ft	% Change	Bankfull Xsec Area Sq Ft	% Change	Mean Depth at Bankfull Ft	% Change	Pebble Count Bed D84 mm 43	D50 mm44
42 41	McQUERY CREEK @ DWD Diversion	Above Below	Straight Straight	A2 A2	7.80 7.70	9.90 8.90	-10	11.61 8.61	-26	1.17 .97	-17	350 350	90 105
44 43	S.FK. RANCH CREEK @ DWD Diversion	Above Below	Straight Straight	A2 A2	8.00 7.30	10.00 4.11	-59	6.82 .84	-82	.68 .21	-69	370 360	135 61
01 03	BEAVER CREEK @ Ditch #2	Above Below	Straight Straight	A3 A3	5.52 6.03	5.70 4.10	-28	3.57 1.99	-88	.53 .78	-36	85 100	40 17
02 04	BEAVER CREEK @ Ditch #2	Above Below	Meander Meander	A2 A2	4.63 5.13	7.20 4.30	-40	5.80 2.19	-62	.81 .51	-37	120 75	32 13
05 08	BEAVER CREEK @ LININGER DITCH	Above Below	Meander Meander	A2 B2	5.64 1.97	7.50 5.10	-32	2.98 1.31	-56	.40 .26	-35	123 10	31 .35
06 07	BEAVER CREEK @ LININGER DITCH	Above Below	Straight Straight	A3 A3-4	5.50 5.88	3.60 2.80	-22	1.65 .63	-62	.46 .23	-35	92 20	23 2.1
15 18	1/4 MILE CREEK @ Skyline Ditch	Above Below	Straight Straight	A3 A3a	8.07 11.18	3.07 0.75	-76	1.76 .14	-92	.48 .19	-60	45 3.8	25 1.4
17 18	3/4 MILE CREEK @ Skyline Ditch	Above Below	Straight Straight	A3a A3a-4	13.30 17.80	7.00 1.90	-73	6.13 0.24	-96	.88 .13	-85	240 3	128 .75
19 20	2 1/2 MILE CREEK @ Skyline Ditch	Above Below	Straight Straight	A3a A3a	19.54 19.40	13.94 11.00	-21	13.68 7.86	-43	.98 .71	-35	360 510	145 135
09 12	NORTH LONE PINE CR @ Mitchell Ditch	Above Below	Straight Straight	A2 A2	9.00 10.88	4.40 3.00	-31	3.57 1.99	-82	.45 .23	-37	620 1300	76 250
10 13	NORTH LONE PINE CR @ Mitchell Ditch	Above Below	Straight Straight	B1 B1	4.80 5.04	6.00 2.80	-53	4.19 .24	-94	.70 .09	-87	128 124	40 31
11 14	NORTH LONE PINE CR @ Mitchell Ditch	Above Below	Straight Straight	B1 B1	4.03 5.13	6.00 6.00	0	2.64 1.30	-31	.70 .49	-30	110 91	50 10
23 26	S. ST VRAIN CR. @ James Cr. Ditch	Above Below	Straight Straight	B1 B1	3.35 2.52	20.80 9.71	-53	22.60 4.19	-81	1.09 .43	-60	500 480	150 205
24 25	S. ST VRAIN CR. @ James Cr. Ditch	Above Below	Straight Straight	A2 A2	3.42 5.01	19.85 5.95	-70	26.88 3.36	-88	1.35 .56	-37	810 710	280 140
21 22	RAPID CREEK @ Rawah Ditch	Above Below	Straight Straight	A2a A2a	41.34 25.61	8.90 0	-100	8.21 No Existing Active Channel		.92	-100	510 .10	250 .06

The data that were collected consisted of pebble counts and subpavement samples to characterize the size of material making up the channel bed, cross sectional measurements for determining bankfull cross sectional area, bankfull width, and mean depth at bankfull. Stream flows were measured both above and below the diversion sites. The channel gradient was measured and the channel was typed using the Rosgen stream classification procedure. Photographs were also taken of each site.

RESULTS

The results of this study verified that changes in stream channels do occur when streamflows are reduced. The survey demonstrated that 91 percent of the channel reaches showed a decrease in bankfull cross sectional area below the diversions. Bankfull widths below the diversions decreased in 85% of the channel reaches. Eighty-eight percent of the channel reaches had a decrease in mean depth at bankfull below the diversions. In addition, 72 percent of the channel reaches exhibited a decrease in the D50 particle size of streambed material.

Cross section graphs of three streams (Figures 1-3) are also shown to illustrate the changes that occur in channels as the flows are decreased. All three streams decreased in bankfull cross sectional area below the diversion. Two of the streams showed a decrease in width.

The graphs of channel bed material (Figures 4-5) show a decrease in size of material in the reaches below the diversion (Table 2). Reduced flows resulted in finer channel materials.

Table 2. Bennett Gulch and North Lone Pine Creek channel bed material pebble counts.

Size Class	Bennett Gulch Above	Bennett Gulch Below	North Lone Pine Creek Above	North Lone Pine Creek Below
D50	129.4	42.9	50.9	9.8
D84	326.5	341.5	109.0	90.8
D95	842.6	787.3	144.2	188.1

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Leopold, L. and Langbein, W.B. 1962. In Landscape Evolution. U.S. Geological Survey Professional Paper 500 A, 20 pp.

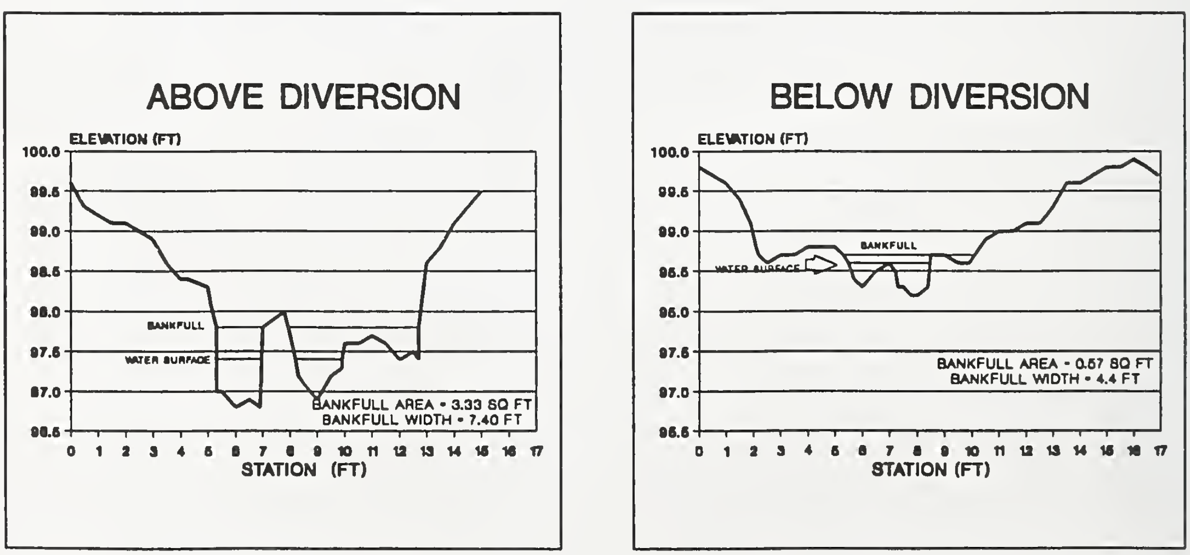

Figure 1. Bennett Gulch cross sections, above and below diversion. 80% reduction in cross sectional area below diversion, and a 40% reduction in bankfull width below diversion.

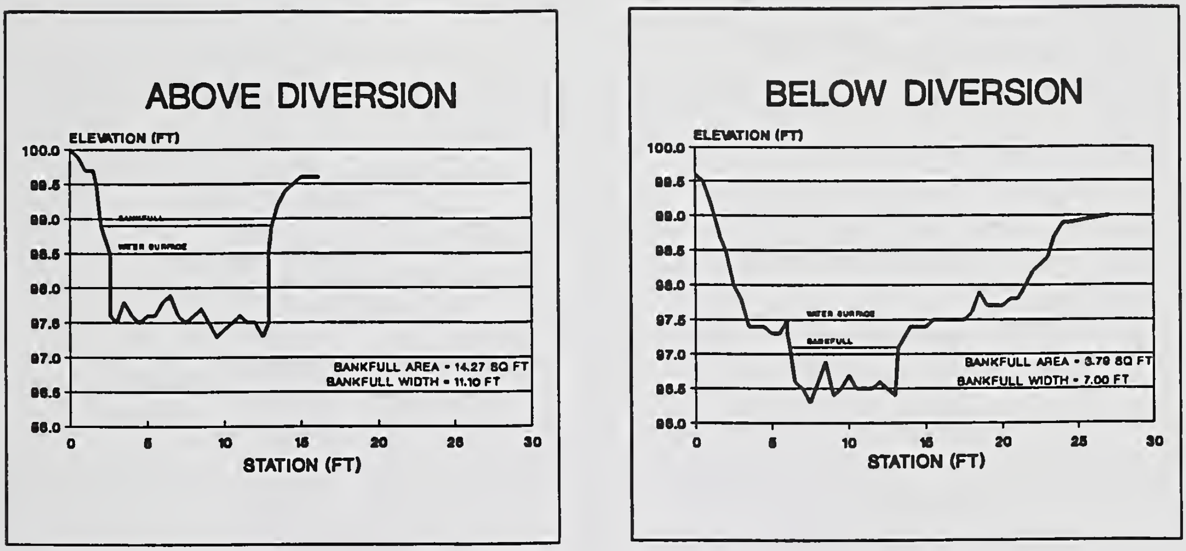

Figure 2. Jefferson Creek cross sections, above and below diversion. 70% reduction in cross sectional area below diversion, and a 30% reduction in bankfull width below diversion.

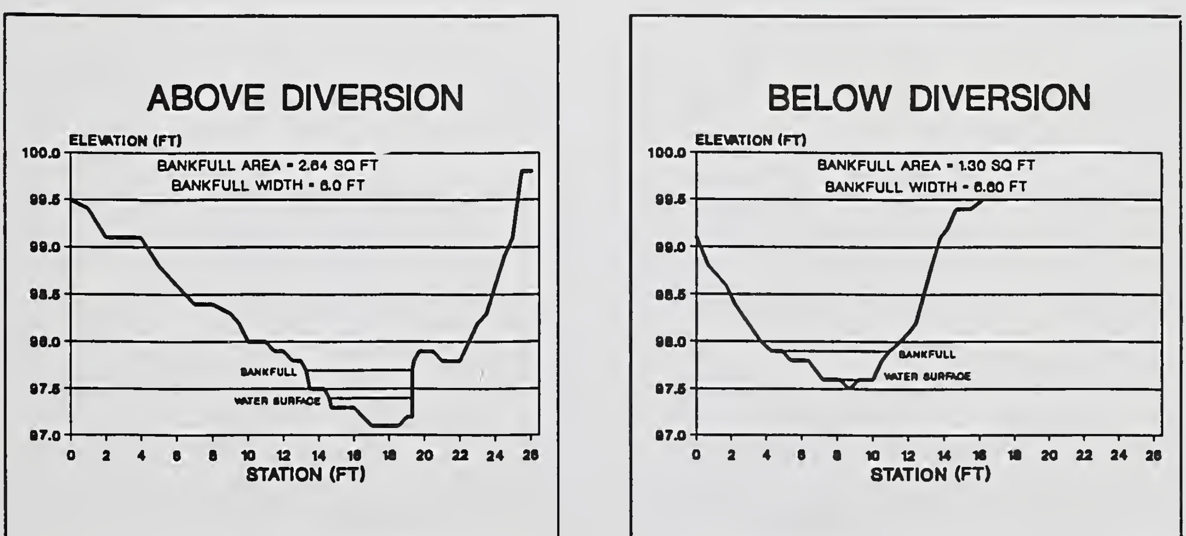

Figure 3. North Lone Pine Creek cross sections, above and below diversion. 50% reduction in cross sectional area below diversion, and no significant change in bankfull width.

CHANNEL BED MATERIAL

	ABOVE	BELOW
D50 (mm)	129.4	42.9
D84 (mm)	326.5	341.5
D95 (mm)	842.6	787.3

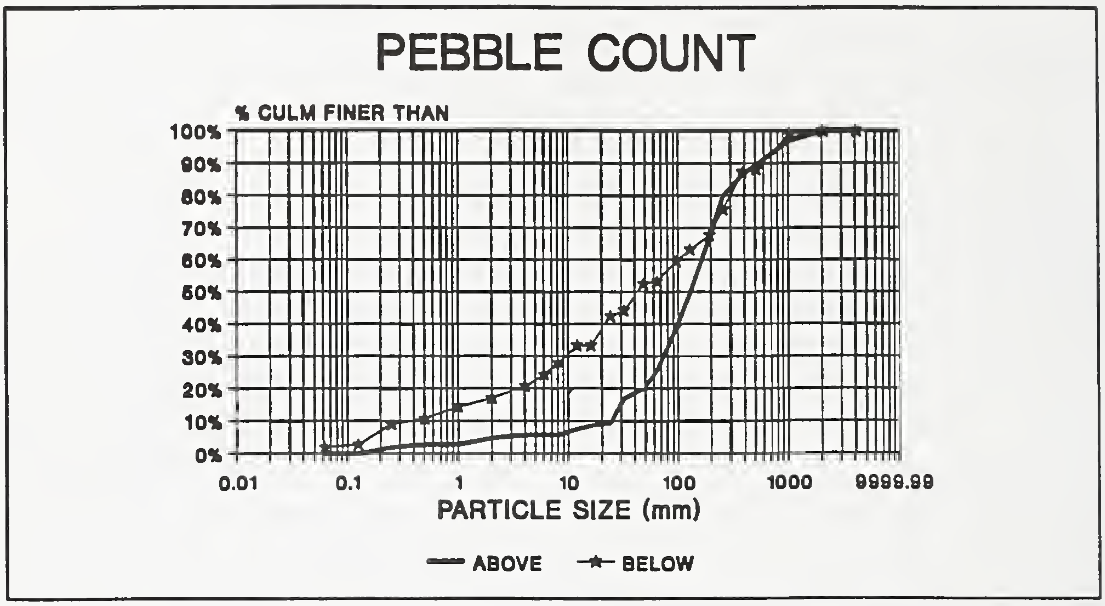

Figure 4. Bennett Gulch pebble counts, above and below diversion.

CHANNEL BED MATERIAL

	ABOVE	BELOW
D50 (mm)	50.9	9.8
D84 (mm)	109.0	90.8
D95 (mm)	144.2	188.1

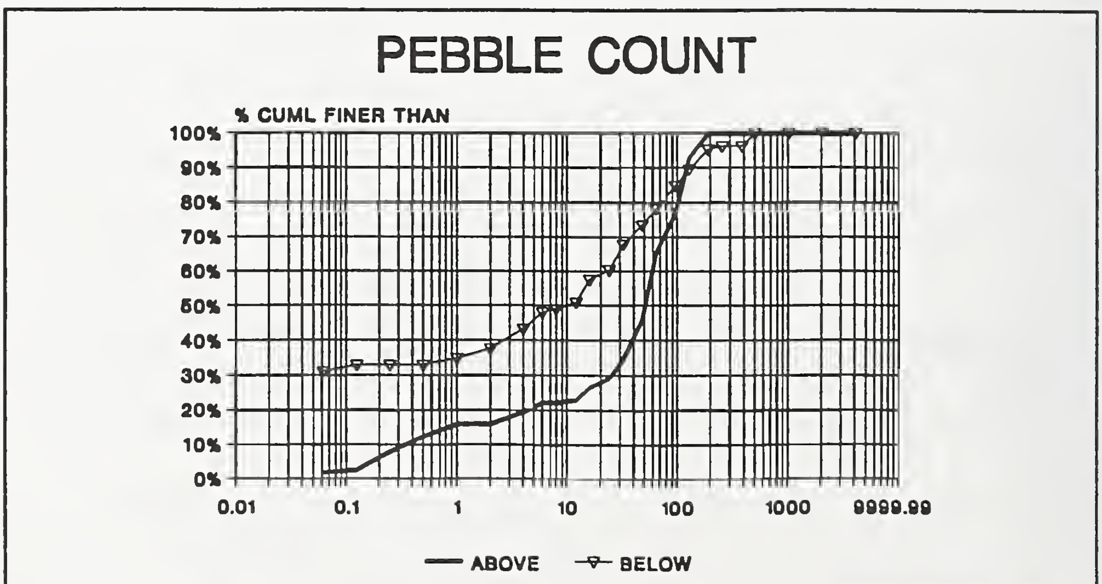

Figure 5. North Lone Pine Creek pebble counts, above and below diversion.

Topics in Sediment Modeling

Charles H. Luce[1]

Abstract.--National Forest hydrologists are being asked to quantify estimates of sediment delivery to channels more and more. These quantified estimates are used as the basis for decisions. Because the estimates themselves are used, the selection of a model can influence the decision greatly, and consequently is being challenged more and more. This paper seeks to increase the comfort of hydrologists in selecting a model by increasing understanding of sediment models in general, and it seeks to encourage responsible interpretation of results, not just using the numbers directly for a decision. Four main points are discussed. Model results should not be considered better or more objective than a professional's opinion. Physically based models should not be considered superior to empirical models. Landslide sediment volumes should be calculated only for large areas; in smaller areas, risk analysis should be conducted on the affected sites. Sediment models are imprecise and should not be considered an engineering tool. In addition, several sediment production models (WATSED, LSDI, LISA, WEPP, USLE, CREAMS, and SPUR) are briefly discussed.

INTRODUCTION

Sediment models are an important tool of hydrologists on National Forests. Decision making through the process described by the National Environmental Policy Act (NEPA) increasingly relies on quantitative assessment of environmental effects, and models can assist in quantifying sediment delivery to stream courses.

The increasingly quantitative nature of NEPA documents comes in an age where challenges to Forest Service management are intensifying. Managers and the public both want to know with some certainty that proposed projects will not increase sediment delivery to such a degree that water quality and fish habitat suffer. To achieve this "certainty," quantification of effects has become the standard.

As presentation of numerical results has become standard, the number of ways to get those numbers has increased. Managers, hydrologists, and the public look from place to place, from NEPA document to NEPA document and see different methods for quantifying sediment delivery. This begins to bring challenges to hydrologists from both managers and the public asking them to justify their choice of model. When different models give different answers, the decision can rest on which model is chosen.

The result can be paralyzing. The question, "Which model should I use?" is asked over and over. With no outstanding models, no benchmarks with which to compare performance, no "model that everybody else uses," the choices can be bewildering. The question is difficult for both new and experienced hydrologists.

It is a difficult question because so much importance is attached to it. There are many models available, many of which a hydrologist may not understand fully. The simple fear of making a mistake, possibly a costly one, is what causes the paralysis, and is probably one of the most irritating aspects of sediment modeling. Many experienced hydrologists have de-

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veloped a sufficient degree of cynicism about modeling that fear is not such a problem as it is for newer hydrologists. The motivation for this presentation and this paper is to reduce that fear and cynicism.

It is my hope that a few pieces of information can calm some nerves and put modeling in proper perspective, neither as an all important decision-producing procedure, nor as a meaningless exercise to get a "number," but as a tool to get one more piece of the puzzle. This provides the paper with two goals:

1. Increase the comfort of hydrologists with sediment production models
2. Encourage responsible interpretation and use of model results

The approach is through a simple overview, which should mostly be taken as food for thought. The first four sections will address some general issues in sediment modeling, and will dispel oppressive myths and present limitations specific to sediment modeling. The last section will present some actual examples of models.

Myth of the Superiority of Models over Professional Judgment

The first myth to dispel is the notion that somehow the answer that models present is more correct or more objective than the professional judgment of a hydrologist. This is fundamental to both goals. Models have been given far too much power in making decisions because of this misperception. Models cannot be a substitute for hard thinking and difficult decision making.

The primary route toward dispelling this myth is to look carefully at models, the part underneath the complex interfaces. The reason that people give models so much "authority" is that models often hide behind an aura of mystery and awe. If hydrologists saw the basis of most models, models would not be used for decision making. At the same time, the answers the models provide would become much more useful.

A model is just a model, and it gives only an estimate. Did you ever notice that the wheels of the plastic models we built as children seldom if ever turned. Well, sediment models are like that. It is feasible only to model part of what is going on, usually the most important aspects or processes; therefore, models are only a partial representation of a complex system.

Many models are built on well-established science. WEPP, considered a state-of-the-art erosion model, uses infiltration technology from 1911, water routing from 1955, and erosion routing from 1980. Model developers usually are searching for practical means to the end of making an estimate, and they seldom desire to test hypotheses of system behavior. The best route to do this is to use established relationships and sub-models.

It is important that each user go the extra step beyond these general statements to understand the model they will use. Conceptually, most sediment models are easy to understand, given some training in hydrologic theory, particularly the large class of models based on the R1/R4 guidelines (Cline et al. 1984). Only when the user understands what the model represents can the results be useful.

Occasionally, you find models that are poorly documented. It is difficult to understand them. Computer code is sometimes useful, since it is completely unambiguous, but it is generally cryptic, and it does not show reasoning behind equations. There is little that can be done to retrieve undocumented models. They are as much trash as unreferenced claims. You can only assume that there is no basis for the equation or algorithm, and that the modeler made it up out of thin air (which is probably true). If you write models, document them to make sure people understand what you've done. Document the strangest and most embarrassing parts the best, because they are the hardest for other people to understand.

Finally, recognize modelers are people, and that their biases, errors, and professional judgment go into models. Models don't portray unbiased truth any better than the people who wrote them. By putting decision making into the hands of a model, you have effectively placed the decision in the hands of the professional judgment of the modeler (who may never have seen the site) instead of the local hydrologist.

Myth of the Superiority of Physically based Models over Empirical Models

A lot of mystery has developed around so called physically based models and their superiority to empirical models. For some reason, models don't seem to be given a fair shake unless they use finite elements and finite difference techniques to solve

partial differential equations. This is great for some applications. For Forest Service hydrologist's applications, both empirical and physically based models are necessary.

A "physically based" model models the components based strictly on basic physical laws and relationships, with no parameters requiring fitting for local conditions. Commonly, they are built around partial differential equations, and use numerical methods to solve them. Models predicting trajectories of objects in a vacuum (like space) are good examples. In hydrology such a model would be able to predict flows and erosion based solely on a person measuring soil particle sizes, packing, and chemical nature without requiring that a particular soil be tested previously and have parameter values fitted for it. No such model exists -- nor likely will during our careers. The closest models in hydrology are infiltration models, like Philip's equation, which requires fitting hydraulic conductivity and sorptivity, and overland flow routing equations, like the kinematic-wave equation, which requires fitting roughness parameters.

An empirical model relates outputs to inputs through fitted parameters. Measurements of outputs and inputs for several conditions are made, and then they are statistically correlated. Such a model might relate erosion volumes as a function of acres of harvest and miles of road. Often they are more complex than this, but this particular formula is at the heart of many sediment delivery models.

Most models are a mixture of empirical and physically based components, so there is more of a spectrum of models between the extremes. For even with empirical models, it takes some understanding of the physical system to develop a good model that represents what is going on.

The question of which one to use lies in the scale of the question. I suspect many of you have glanced through James Gleick's book, Chaos, and seen the fractal images and Mandelbrot sets, which illustrate that things can look very similar at different scales. This is a familiar situation in geomorphic settings. In general if you look at a river system from up high, it looks similar to looking at a branch of it from lower. This would suggest that a model should apply at many scales. Why can't we just pick one model and use it at whatever scale we like?

The more physically based a model is, the finer the resolution of measurement is required to run it. While we have point infiltration models and overland flow models that are physically based, they require that the infiltration capacity be modeled on scales of feet; any attempt to generalize by applying the same hydraulic conductivity to an area larger than 2 to 3 square feet requires characterizations that are functionally performed by empirical methods.

The larger the individual cells modeled, or the coarser the resolution that is used, the more and more parameters become lumped, and the more and more empirical a model must become. Because it is impractical to model even a single harvest unit with fine resolution, most modeling is at least partially empirical.

The primary advantage of using physically based models is that they require little calibration, so they can be used in areas where calibration data is not available. Usually you can calibrate components through controlled experimentation rather than relying on long-term measurement and monitoring programs. Experiments can further pin down effects of forest management. Physically based models can be put to practical use in single site analysis, a potential failure site for instance. They may also be used in general behavior descriptions, in the way a flight simulator might be used.

Empirical models must be calibrated for local conditions. Calibration data are seldom available, but you know what they say..."There is no time like the present." This is a great use for monitoring data. Once you have established what model you are using, your monitoring requirements are constrained by the outputs and inputs of the model. Use your best guess now and establish monitoring that will eventually be used to calibrate, and improve estimates for later projects.

Physically based models and empirical models are used at different scales and for different purposes; neither is superior. Physically based models are best suited to analysis at a particular site and to demonstrating the physical basis to professional opinions. Empirical models are suited to larger scale simulation where an estimate of sediment volume is desired.

Quantum Nature of Landslides

A unique issue in sediment modeling arises out of the quantum nature of landslides. Landslides happen in units. You don't get partial landslides. When you get one, it usually dominates the sediment input to that particular stream section, and it doesn't matter

how much surface erosion there is. Studies in the southern Oregon Coast Range are showing on the order of 2500 yd3 for landslides and 50 yd3 for large gullies.

Consequently what is important is the yes/no answer. Happen or not happen. For a single landslide site, or hollow, you cannot take its likely volume and multiply by the probability of occurrence as might be done for money. For example a 10 percent chance of winning 2,000 dollars can be assigned a value of 200 dollars, but a 10 percent chance of delivering 2,000 yd3 cannot be assigned a value of 200 yd3. If 2000 yd3 hits the stream, the impact will be very different than if 200 hits it. Risk analysis is a more appropriate way to present results for a single hollow or a few hollows.

This concept has been worked over and over again by nuclear physicists. As many of you learned in high school and college, things like electrons, and protons, muons, and otherons come in discrete packages. In time, physicists learned that statistical descriptions of position and momentum were the only feasible means to describe movements of these particles.

One scientist who helped develop the field of quantum mechanics coined the concept of the cat in a box, which became known as Schroedinger's cat. Here is how it went (my apologies to cat lovers). At the end of a complex experiment, the experimenter was able to see the results of the experiment by lifting a box to see if a cat was dead or alive. The question was how do you describe the cat before you lift the box. Dead and alive are mutually exclusive states; there is no half-dead, half-alive outcome. You certainly couldn't describe it as half a cat for then it would most certainly be dead. The result was that you could describe probabilities of state for an individual cat, which is useful if you are concerned about the cat's welfare, but useless when considering an individual particle. Extending his concept to a large number of particles, the concept becomes more useful, and many more tools can be brought to bear on it.

Likewise for landslides; if you consider a large number of potential failure sites, usually as a watershed, you can apply traditional statistical tools and get the expected number of failures and the range of likely answers. For example, a 10 percent probability of failure applied to 100 hollows would give an estimate of 10 slides, and it is physically possible to get 10 slides.

This quantum nature of landslides also tends to produce higher variability in sediment predictions for landslide models. Because landslides happen in 2500 yd3 chunks, the landslide rate (slides per acre per year or slides per mile per year) becomes an extraordinarily sensitive parameter. At the same time, it has a high coefficient of variation when measured from aerial photographs. The result is relatively imprecise estimates of sediment volume.

Imprecision in Sediment Modeling

Finally, I would like to discuss precision. This concept has been badly ignored in sediment modeling.

The sources of uncertainty in sediment modeling are numerous. Input data are uncertain. Mapped information is uncertain. Constants and fitted parameters are uncertain, and you can only make a guess at the weather. Finally, many of these models represent only a portion of the processes occurring, and the unaccounted for effects give some uncertainty in the relationship of the estimate to the truth.

It is surprising to find how imprecise these models are. They give a very rough notion as to how much sediment will be delivered. The truth of how much will actually land in the stream is within a very broad band around the mean estimate.

In work done with a model used on the Siskiyou National Forest (NF) (Ricks and Luce, unpublished work), I found that the 90 percent confidence interval for landslide sediment delivery from an individual harvest unit was between 4 times and 1/40th of the mean, so that the maximum was 160 times the minimum. The coefficient of variation for landslides per acre was about 2, and the coefficient of variation for volume per slide was about 1.5. The upshot was that the truth was still between no increase over background and complete destruction of the watershed.

The model was well reasoned, and constructed similarly to the way the R1/R4 guide suggests for surface erosion. It is a great improvement over the way the R1/R4 guide suggests to do landslides. The data from which it was constructed were carefully collected, and corrections were made to the data set over the years. It is a far more carefully collected and maintained data set than most people can expect to reasonably have. Yet it still yields a large confidence interval.

The reasons are as discussed earlier. Among them is that it is a landslide analysis applied to a relatively small area. Another is that the analysis is done by aerial photograph interpretation, which is the only reasonable way to model over a large acreage on short notice.

"So," you ask, "if this great data set and well-reasoned model gives such a large confidence interval, my model probably gives even bigger ones. What can I do?" First, you can recognize that imprecision is a property of sediment models. The reasons have been listed. Just state in your analysis that the results are not exact, and do not try to use them as an engineering tool. We cannot engineer sediment input to streams as yet.

If you are lucky enough to have the calibration data, you can calculate and present confidence intervals with your analysis, to indicate how wide a range the answer lies within, and provide interpretation. This method is honest, and displays quantitatively how uncertain you are of the model's answer.

One advantage here is that if the uncertainty is too great for the decision makers, then they will eventually find time and money to reduce the uncertainty. Information has value, and a cost must be paid to reduce uncertainty. Obviously having a rough notion has some value to decision makers; that is why we model. They may not feel any need for more precise answers, in which case, you can stop searching for a better model; but they may also not know how rough the answers are. Sometimes by displaying single values, we give the impression that these models can be used to engineer sediment inputs; that impression should be removed.

Another unique advantage is that if you are asked in a courtroom, "I don't see XYZ explicitly in your formulation; did you consider XYZ?", you can reply that 90 percent of the time XYZ is considered (assuming you are displaying a 90 percent confidence interval) because the purpose of the confidence interval is to display that which is not accounted for by the mean.

Another solution is to do risk analysis, which means that you present the probability that one or more targets are exceeded. This can be used to show the cost of having an uncertain model to a decision maker. This requires that you have the calibration data again.

The lack of precision also dictates that one should use the model solely for comparison between the alternatives. This means no comparison to thresholds. This is the only reasonable way to use those single numbers if you cannot display the range of possible answers.

Finally consider your sources of uncertainty. Where in your model is the input most uncertain, or where in your model will the uncertainty that is present blow up and dominate uncertainty from other sources. This asks the question "Where will I get the most bang for my study and monitoring efforts?"

If the range of values that the sheet erosion section of your model provides is smaller than the range that the landslide section does by an order of magnitude or more, you should realize that it is probably not worth your time to fine tune the sheet erosion model. For those from an older school, it is of little use to have your vernier scale in the right place if the big knob is out of whack.

Uncertainty is a fact of life with sediment modeling. Sediment models have poor precision, partially because complex systems are difficult to represent and partially because we typically do not have time to provide inputs on a fine scale. We must present the uncertainty in model outputs, either through calculations or a simple statement.

SEDIMENT MODELS

This final section presents a few of the models that are available for predicting sediment input to streams. The examples should increase your comfort in selecting a model. I will discuss only a sampling of sediment models, and some in more detail than others. The first four are models with which I am personally acquainted and have done some work. The others are very popular or notable models, and I throw them in just so that people have an idea as to what is available.

WATSED (and other R1/R4 Derivatives)

WATSED is a model that predicts annual sediment delivery and peak flow increases and routing to sensitive areas from all sources for a watershed (USDA 1991). It is in use on several Forests in Region 1, and will be used on more. It is the most recent of a

class of models derived from the R1/R4 guidelines for sediment prediction. Models of a similar type are very widespread in use and are typically called Equivalent Clear-cut Area (ECA) procedure models. Interestingly, the calculation procedure in this class of models is almost identical to the calculation procedure for Equivalent Roaded Area procedures, which typically are used to predict peak flow increases.

The class is empirically based, using the erosion data that Walt Megahan collected in the decomposed granitics of the Idaho batholith as a basis for the surface erosion curves. The Intermountain Station Engineering Research Unit (RWU-4702) is conducting studies that are being used to expand the number of soil types used by the model. The model requires empirical data from each basin to calibrate it, including natural rates of sediment delivery and landslide information. This information is input by mapping units, which change from forest to forest, but are typically aerial photo based.

The model is mostly an accounting model, and the calculations it performs are of a simple nature. The constants and multipliers are stored in tables that are accessible to the user, and in fact the tables must be filled with values input by the user through the calibration process. The road erosion section for example multiplies the miles of road in a particular mapping unit by the standard erosion rate on that land type for a "standard road," reducing the erosion over time, and multiplying by the percentage delivery for the land type. A combination of soil, vegetation, and geomorphic setting defines a land type. Some users have gone a step further and modified it to account for other than "standard" roads.

On the good side, it is very adaptable to local conditions and has a very open and clear procedure. The developers are to be applauded for their commitment to having a model that can be understood. On the down side, it will require an individual forest or district an immense amount of effort to collect the data necessary to calibrate it. Even for those locations fortunate enough to have data appropriate for calibration, it will be a large task to figure out the values for the large number of parameters and do the mapping. Substantial pioneering work done by the Idaho Panhandle NF will help. The landslide portion of the model is somewhat oversimplified, but its simple structure allows for modifications to correct that in time.

Research ongoing to modify the model concentrates on soil types, roads, and mitigation. A research need for the model is ways to reduce the parameterization work for each forest.

LSDI

The Landslide Sediment Delivery Index was developed by the Siskiyou National Forest (Ricks and Luce, unpublished work). It is constructed similarly to the ECA class of models. It calculates the volume of sediment expected following harvest and road construction during a specified interval.

The calculation procedure is again very similar. The acreage in each land type is multiplied by a constant (fitted empirically for the local area), discounted over time, and a percentage is delivered to the stream. Land types are defined by geomorphic setting and bedrock geology. A similar process is followed for roads.

The only reason that I bring it up here is that it also has a method for predicting the confidence interval. Because it is constructed so similarly to so many other models that are in common use, the same process can benefit many other models.

LISA

The Level 1 Stability Analysis, developed by the engineering research unit of the Intermountain Station (RWU-4702), predicts probability of failure for a site or several sites (Hammond et al. 1991).

It is based on the infinite-slope force-balance equation, which is used to calculate the factor of safety. All the forces holding the slope in place are balanced against those pulling it down. A factor of safety less than one is unstable, and a factor of safety greater than one is stable.

The LISA model throws in one more twist, the Monte-Carlo approach, so named because choosing the parameters for a particular calculation of the equation is like getting a number from a roulette wheel. Each parameter, such as cohesion, root strength, angle of internal friction, and soil depth, is given a distribution, a range, in which it may lie, and a random number generator is used to pick a value from that range. The force-balance equation is calculated several hundred times for each site with a value for each parameter picked randomly from its distribution each

time. The number of times a failure is predicted divided by the total number of times the model is run gives the probability of failure for the site.

This type of analysis is considered a risk analysis and is another possible way to use calibration data to quantify uncertainty. In this case, uncertainty about parameters for landslide formation at one site is covered.

A similar model that can be used for roads by incorporating analyses other than the infinite slope analysis is also being developed under the name of SARA (Stability Analysis for Roaded Areas). Research continues on these models to relate groundwater rise to rainfall conditions, so that simple climate data can be used.

WEPP

The Water Erosion Prediction Project is where I've concentrated most of my personal model development work. The Agricultural Research Service is responsible for most of the development, and the Forest Service's work has been in parameterizing and adapting it to use for forest roads and possibly harvest areas.

It models sheet and rill erosion and is touted as a replacement to USLE. It models annual sediment output through a series of years or sediment output from an individual design storm (Lane and Nearing 1989). It is capable of continuous simulation and includes components that predict plant growth and decomposition, so that it can represent a greater range of management practices. It is also capable of representing complex slopes and varying vegetation and soil conditions down the slope.

Its basis is in differential equations that control infiltration, overland flow, and sediment movement. It is one of the more physically based models available, although determination of parameters is largely empirical. Methods used that might be familiar are the Green-Ampt infiltration equation and the kinematic wave method for routing overland flow.

Calculations and model structure are quite complex, and at this time relatively poorly documented. It is logically constructed though, and a patient student should be able to eventually decipher it. Again many of the methods are familiar.

On the up side, it is being designed with users in mind, so it should be relatively easy for a forest to put into use. Its precision will relate to the precision of inputs. It will have the support of the research organization in fine tuning parameters. On the down side, it is not ready for general use yet, and probably will not be for a couple of years.

USLE

The universal soil loss equation is an old standby and has been used as the basis for erosion on the inside of many other models. It predicts average annual soil loss by sheet and rill erosion from a plane surface (Kirkby and Morgan 1980).

The formulation is fairly simple with empirical factors. It has the familiar form

$$A=RKLSCP$$

where A is the soil loss (M/L2T), R is rainfall erosivity (by location), K is soil erodibility, L is the slope length factor, S is the slope gradient factor, C is the cropping factor, and P is the erosion control practice factor. Other factors are occasionally added to take account of other processes.

The USLE is on the empirical end of the spectrum, with each factor needing to be fitted. Fortunately there are years of data from many plots with which to work. Most of these plots are on agricultural and pasture land, however, and are of little use for most forest practices.

The primary disadvantage of USLE is that it cannot account for changes in the hillslope moving up and down the slope in such a way as to predict erosion from one area depositing in another. Even the newer versions, the Modified (MUSLE) and Revised (RUSLE), have this limitation.

CREAMS

CREAMS simulates Chemical, Runoff, and Erosion from Agricultural Management Systems (Knisel 1980). It predicts water runoff, sheet and rill erosion, and chemical fate from croplands. It can simulate events as well as average annual movement and production. It is another of the class of comprehensive models that model everything relating to the pro-

cesses, like plant growth and tillage. WEPP is an outgrowth of CREAMS and careful examination shows the parentage. CREAMS proved not to be very popular because it is difficult to use, and WEPP is designed to be more convenient to use and improve simulation of some processes.

CREAMS uses a partially empirical and partially physically based formulation. It uses the curve number approach to estimate runoff and USLE to estimate hillslope input. Both of these elements have parameters that should be determined empirically. It routes water and sediment through a channel system with a more physically based approach but still requires some fitting for roughness.

SPUR

The Simulation of Production and Utilization of Rangelands model estimates sheet and rill erosion along with a variety of other variables (Wight 1987). The model was also built to estimate plant and animal growth and do economic analyses. The hydrology and erosion simulations are derived from CREAMS. The hydrology is based on curve numbers as is CREAMS, but the erosion shows some improvement, using sediment transport equations in place of USLE. Unit hydrograph routing is used for channels, and transport equations are again used to predict sediment movement through channels as washload and bedload.

CONCLUSION

The purpose of this paper was to make the task of model selection easier and improve the use of the models. All too often hydrologists have been asked to use a model for their input to NEPA documents without benefit of the time to survey available models or fully study the one they are asked to use. This has led to misuse of model results by managers and a degree of nervousness in the hydrologists who prepare those results. This paper has touched briefly on a few issues in sediment modeling and presented a simple overview of a few sediment models in order to reduce the misgivings of the rushed hydrologist.

Models are sometimes considered more valid and more objective than a professional's opinion. This belief, held by some managers and new professionals, is both wrong and damaging. Models represent a few processes, and the processes the modeler chose to model may not be the most important ones in a particular area. The method chosen to simulate a process may also have biases. Only through the professional judgment of a trained hydrologist may the appropriate model be selected, and even then, only through interpretation of the results through that judgment may the model be of any use. Models provide only an estimate, a piece of the puzzle from which a hydrologist can synthesize the story of a basin.

Physically based models, those based in partial differential equations and their solutions, are often considered superior to empirical models. The truth is that all models have a mixture of empiricism and physical basis and that models at both ends of the spectrum are needed for a complete tool set. Physically based models are better adapted to modeling on-site sediment production because of the fine resolution required for data input and because calibration data is often not available for small areas. Empirical models are better suited to large-scale analyses because relationships between information that can be collected from aerial photographs and sediment production can best be done through statistical methods.

A unique problem in sediment production modeling in areas with landslides is that landslides must be considered as whole units. Results that indicate partial landslides entering a stream are useless and can be considered only in terms of probability. This is sort of like the proverbial two-and-a-half child family; nobody has half a child or half a landslide. When an area with a sufficiently large number of potential failures is analyzed so that rounding to the nearest whole landslide does not constitute a major error, sediment volumes can reasonably be predicted. For smaller areas, risk analysis at individual sites is the most appropriate method because merely the occurrence or non-occurrence of a landslide is the major concern.

Sediment modeling is imprecise. The 90 percent confidence interval calculated on one model was between 0.025 and 4 times the mean on single harvest units. Such a large range suggests that we cannot use these models as a basis to engineer sediment input to streams. It is important that the uncertainty in these models be displayed, either through general statements or through actually displaying the confidence interval.

A great many sediment models exist. Many are of a similar nature and many share the same building blocks. The sample given shows several of these basic building blocks. Hopefully an awareness of the types

of models available can give newer hydrologists or those with little exposure to modeling a higher degree of confidence in their selection of model.

I toss out these tidbits to encourage people to look further. A little bit of knowledge is indeed dangerous, and you cannot expect to know everything about modeling after reading this little paper. This paper only intended to increase comfort of hydrologists around sediment models and encourage the responsible interpretation of results. I hope that the reader will now feel stimulated to study the model that they want to use in some depth and learn its assumptions. There is probably no need to change the model if it looks imperfect; just use it and interpret the results in light of your understanding, and you will receive many hours of enjoyable use.

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USDA Forest Service's National Wetlands Research Program

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Abstract.--This paper relates the genesis of the Forest Service's National Wetlands Program, and gives a regional summary of some important wetlands and riparian research accomplishments of its eight research stations. Key program areas for future emphasis are also identified.

INTRODUCTION

While the total acreage involved may be small when the entire landmass is considered, the importance and value of wetlands far exceeds their extent. Of the 191 million acres for which the Forest Service (FS) has management responsibility, approximately 12 million acres have been identified as wetlands and riparian areas. These wetland ecosystems are critical avi- fauna habitat, both for breeding and for waterfowl flyways. Wetland and riparian systems play a major role in flood control, in the modification of water quality, and in food chain support. Additionally, wetland and riparian areas, especially in the Western United States, provide habitat for numerous rare and endangered plants and animals. In the maintenance or enhancement of biological diversity, wetlands and riparian areas are an essential part of the landscape. Economically, timber production, fisheries, and recreation vie as primary users of forested wetlands.

In May 1991 the Chief of the Forest Service identified wetlands as a national program, commencing FY1993. The identification of "wetlands" as a priority program in the FS reflects their importance wetlands as a major water issue in the minds of the general public, industry, and legislators.

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CURRENT PROGRAM

Forest Service Research is organized geographically into eight stations, and while some research within each station is specific to its region, much of the research has national implications. Some of the earliest research done by the FS focused on watershed management with emphasis on waterflow and quality; landscape features include riparian and wetland sites. Several of these experimental watersheds have been studied for over 50 years and are internationally recognized. These include Coweeta, H.J. Andrews, Hubbard Brook, and Fernow. And research relevant to wetland issues has been a part of FS activities in many other locations as well.

Intermountain Station

Research on riparian areas has been a key emphasis in this region, with a mission to develop an improved understanding of riparian and stream habitats. Other studies focus on improving methods for habitat management, for conservation of resources, and for production of livestock, wildlife, and fish. More recently, an interdisciplinary team comprised of fisheries biologists, hydrologist, soil chemist, botantist, and management specialists will be focusing on the enhancement of salmonid fisheries habitat. Research has consistently examined the role of riparian habitats on the landscape as islands of diversity (including the abiotic characteristics of these habitats). For example, studies have determined that 59 percent of small land birds in western Montana

use riparian habitats during the breeding season, while 53 percent of Idaho's neotropical migrant land birds use these areas for breeding habitat.

The same features of riparian areas that attract "wild" species also make these systems preferentially used by livestock. Research has described the degradation of many systems due to overuse and has made significant progress in rehabilitating damaged ecosystems. Fundamental research on plant community succession following restoration is ongoing as are basic phenological studies of important riparian species.

North Central Station

The region is a complex ecosystem of uplands, wetlands, lakes, and streams, where recreation shares land-use with timber production. The Station has been studying the peatland ecosystems since the 1950s with much of the work done on the Marcell Experimental Forest. Research has focused primarily on the formation and hydrology of northern peatlands, including biogeochemical cycling of these systems. Recently, studies have been implemented to analyze the impact of acidic deposition on peatland chemistry. Efforts are continuing to examine methane production and CO2 flux from Northern peatland ecosystems.

In addition to fundamental studies on wetland processes, researchers are examining also cumulative effects of alternative management systems. This research is coordinated with the forest engineering project which is developing harvesting techniques and technology for use on unstable soils.

Northeast Station

Research on wetland ecosystems has been done within the watershed studies, and therefore, the data collected primarily have been total hydrologic budgets, which can be used to evaluate subcomponents. For example, systems analysis of western Kentucky wetlands showed that water level controls the communities that develop on the wetland. Due to the concerns related to coal mining in the region, experiments are currently being conducted to determine the efficiency and longevity of artificial wetlands in treating acid mine drainage.

Pacific Northwest Station

Wetlands research in this part of the United States is dominated by efforts in Alaska. Many unique ecosystems occur in Alaska including 40 million acres of forested wetlands. Much of the research has emphasized the forested landscape of the southeastern panhandle, including some characterization of associated wet-muskegs and riparian areas.

The most significant opportunity for wetlands research lies within the Copper River Delta (CRD). It stretches 75 km along the south central coast-line of the Gulf of Alaska and is rich in waterfowl and fish habitat. Studies have looked at vegetation communities as related to moose feeding habits. Moose on the CRD use the wetland community primarily for feeding and the upland forest community primarily as a bedding area. The dynamic nature and diversity of the ecosystem will serve as the basis for planned fundamental research on the structure and functions of complex delta systems.

In Oregon and Washington research has concentrated on riparian habitat restoration and management in association with other management activities. A descriptive system for streamside management units based on water quality and fisheries habitat has been developed.

Rocky Mountain Station

Scientists in Arizona, have led the research effort to understand the functioning of riparian areas in the Southwestern United States. Initial focus was on animal (domestic and wild) interactions in these systems. Generally, research has emphasized the management of riparian areas to enhance, maintain, or restore vegetation and hydrologic conditions in these ecosystems. Research has resulted in management guidelines for use in the field as well as basic information on flora and fauna composition and distribution. Ongoing studies deal with the structure, function, and composition of these ecosystems and the interface with the aquatic system (fish and water). Studies are being done on channel dynamics and on water table controls on riparian vegetation. The impact of livestock grazing on riparian areas is a major emphasis

area throughout the Rocky Mountain west, as evidenced by similar research in the Intermountain Station.

Southeastern Station

There has been a long history of research in Southeastern wetland systems, focusing primarily on stand productivity in pocosins (Croatan NF) and bottomlands (Francis Marion NF/Santee Experimental Forest). Water management studies in pocosin-site, pine plantations in North Carolina have shown that stand transpiration, direct evaporation, and drainage outflow account for about 60, 20, and 17 percent, respectively, of gross rainfall. The proportion of gross rainfall for an unditched natural pocosin attributed to drainage was 18 percent. This research has applicability for both public and private lands throughout the pocosin community type.

To provide greater focus for wetlands research in the region, the Center for Forested Wetlands was established in 1988 in association with Clemson University at the Forestry Sciences Laboratory in Charleston, South Carolina. Emphasis has been on growth and productivity of wetland tree species under different management activities, with special attention being given to studies of soil chemistry and the role of flooding on plant physiology. Hurricane Hugo has provided a new opportunity to evaluate effects of catastrophic disturbance on the hydrology and biogeochemistry of forested systems, including wetlands. Efforts are increasing in the area of wetland restoration both at the Santee and at the Savannah River forest site.

Research has recently been initiated to examine the use of buffer strips to protect forested wetlands from impacts due to upland silvicultural operations. These areas have demonstrated high potential to reduce transport of nutrients, pesticides, and sediment from silvicultural and agricultural practices to adjacent surface waters. The greatest value of wetlands in the landscape may be as transformers as these ecosystems maintain the widest range of oxidation/reduction reactions of any ecosystem.

Southern Station

Bottomland hardwood forestry research began at Stoneville, Mississippi, in 1937 and — while the specific problems have changed — the basic mission is current: to study regeneration and management of Southern hard woods. Locations of concern include the Mississippi River Delta with associated swamplands as well as other major and minor drainages in the central South. Emphasis is increasing on natural regeneration methods for even and uneven-aged forests. One system of concern is the bald-cypress swamp forest where human-induced changes in hydrology, natural subsidence, and the introduction of nutria have reduced regeneration success. Efforts to regenerate bald-cypress by planting resulted in 86 to 100 percent seedling loss to nutria unless care is taken to protect the seedlings until established.

Scientists are studying both growth and yield and insect and disease problems, as well as examining the role of these wetland systems at all stages of growth as wildlife habitat. Factors include habitat age or successional sere, size of area, species composition, structure, landscape context, and hydrology.

Other areas of research are engineering and economics. Just as in the North Central states, the management of bottomland sites has necessitated the evaluation of harvesting methods leading to systems for reducing site impacts on wetland forests. Researchers continuously monitor and analyze Federal and State wetland regulatory laws as they relate to forest management and forestry practices. Research has also been done on the economics of converting forested wetlands to crop production in the Lower Mississippi Alluvial Plain.

FUTURE PROGRAM

Scientists and managers from the eight research stations met in 1991 to identify critical research areas for the Forest Service's Wetlands National Problem Area. The discussion acknowledged that a significant amount of re search on wetland ecosystems or related to wetland and riparian issues has been done by FS scientists. The new program must build on what has been accomplished, but we also must target research to deal with the new and emerging issues in wetland protection, restoration, and management. We also must recognize that other agencies, especially the Fish and Wildlife Service, Environmental Protection Agency, and the Army Corps of Engineers, have important research programs already underway. FS Research must both build on this existing research and be complementary to these efforts.

The following section identifies program bounds, program elements, and criteria for prioritization of research.

Program Bounds

The purpose of this section is to provide some guidelines regarding what types of ecosystems would be studied within the FS program. The recent controversy regarding the 1991 Revised Federal Manual for Delineating Wetlands raises concerns about how wetlands should be defined for research purposes. The geographic and physiographic positioning of wetlands also must be considered, particularly with regard to the extent of riparian studies within a wetlands program. Some guidance is provided below; how ever, it is acknowledged that the scope and/or emphasis may change over time as technical and political issues change.

1. The primary driver of wetlands issues comes from the South and the urbanizing East—the interest and concern that is focused on management practices as they affect wildlife and waterfowl habitat or timber harvesting. However, there are other geographic areas that are just as important but which have not attracted national interest. Local and regional concerns regarding developmental pressures, no-net-loss and mitigation, and wetland restoration are widespread. It is important and necessary to have a way of addressing these issues.
2. FS Research needs to identify scientific gaps in our wetlands understanding, and to tailor our program accordingly; research emphasis in each region of the country should reflect local issues. In the East this means listening to the multiple-use concerns of private landowners. In parts of the West, the issue may be streamside wetland restoration from grazing or restoration of the marshes along the Pacific Coast. In coastal landscapes, estuarine environments have been incorporated into some FS Research efforts, especially those dealing with anadromous fisheries.
3. Jurisdictional wetlands should be considered but research should not be limited to these systems as regulatory definitions will continue to change. Utilization of the definition will limit the extent of riparian areas and other valuable systems that would be included in a wetlands program. FS Research should use the wetlands definition stated in the 1989 Federal Manual for Identifying and Delineating Jurisdictional Wetlands, which reads as follows: "Wetlands are defined, under Section 404 of the Clean Water Act, as those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs, and similar areas.'"
4. Geographically, the areas of greatest interest are Southern bottomland hardwoods and Southeastern coastal fringe wetlands, peatlands in the North central and boreal regions, and riparian wetland habitats in the West. The proposed research program will emphasize these areas, but will not exclude other locations identified as high priority by specific research stations.

Program Elements

The program to be initiated in FY 1993 is comprised of five broad categories of research encompassing a range of subelements. In the following presentation, questions are identified for each category as well as several key issues which further elaborate on scope. Elements identified should be considered over a 10-year timeframe; therefore, not every element will be studied in FY 1993. Similarly, some elements are of interest or an issue only in particular regions of the United States; therefore, not every station will pursue all elements.

Cooperation with Other Agencies

The research elements which are described will overlap with the research emphasis of other agencies. This program plan has been developed with input from the U.S. Fish and Wildlife Service, U.S. Army Corps of Engineers, U.S. Geological Survey, and the Environmental Protection Agency. In identifying elements, an effort was made to recognize those areas of research for which the FS is uniquely qualified and to complement ongoing research efforts. Progress has already been made in the southern United States

through the Consortium for Research on Southern Forest Wetlands. A regionwide joint study to assess the functions of forested wetlands has been developed by the Southeastern and Southern Experiment Stations, in cooperation with the National Wetlands Research Center (Fish and Wildlife Service). The participation of FS Research on various interagency coordinating committees dealing with wetlands is an important mechanism to ensure continued cooperation.

Ecosystem Processes

How do wetlands function, and how do natural and human-induced disturbances alter these functions? Important keywords here are dynamic models, growth and yield, bottomland hardwood stand development, inventory, ecophysiological processes, insects and disease dynamics (hardwood decline/defoliators), greentree reservoir, water supply, dewatering, stand degradation.

Important research topics are:

1. Predicting stand/community structure and compositional changes, integrating ecophysiological processes, through the development of ecosystem models. Modeling activities will range from whole system conceptual models to more detailed submodels; however, the intent is to be able to evaluate wetland ecosystem changes driven by key processes or management activities. Also included would be models that describe short-term (e.g., within a rotation) responses to predict event effects on the stand.
   The support of research studies to strengthen model development is considered withinthis element. Research may include above- and below ground competitive processes as they affect species composition along nutrient and hydrologic gradients.
   For example, data are being accumulated on how changing water tables and water chemistry affect plant physiology or competition, and how that in turn would change the plant community. Communities of special interest are bottomland hardwoods, cypress-gum swamps, pocosins, riparian areas in coastal redwood sites, peatlands, and northern boreal forests.
2. Understanding the hydrologic regime of wetland systems, including patterns of temporal heterogeneity. Variables of interest include timing, duration, and seasonality of water flux, and the control on successional structure. Linkages should be made to plant physiological processes, including transpiration and net primary production.
3. Interrelationships of water quality and quantity on wetland "health." Health refers to structure, species composition and productivity of the wetland ecosystem. Research work will identify reference wetlands (undisturbed and typical) for use in evaluating functions. Inventory and monitoring are key components of this research element. Water quantity and quality also are influenced by streamside zone characteristics and functions.
4. Understanding natural patterns of disturbance as part of the baseline characterization.
   This effort should consider impacts on wetland structure and function. A management question would consider how wetland health is affected by upland inputs.
5. Influence of herbivory on structure and function of wetland ecosystems. Included here is a consideration of all forms of herbivory, from defoliating insects to wildlife and livestock. Some emphasis will be placed on successional development and the changing impact on wildlife habitat.
6. Habitat in relation to faunal communities and requirements for supporting a viable population. Consideration should be given to describing the faunal component of wetland habitats and evaluating impacts of habitat management. For example, in greentree reservoirs where annual flooding is resulting in oak declines, will the reduction in mast alter the duck population? A consideration can also be given to

the effect of operational streamside management zones (SMZ) on faunal communities, including SMZ width.

RESTORATION AND REHABILITATION

To what degree can desired functions be restored, and what degree of difficulty is associated with their restoration? What techniques are available to restore desired functions? What is the measure of success? Important keywords here are degraded or dysfunctional sites, CRP, regeneration, structural, functional, short term vs. long term, natural recovery, enhancement.

Important research topics are:

1. Determine the restoration potential of degraded or lost wetland systems through hydrologic manipulation, stream channelization, and revegetation. Systems of concern for primary restoration include old fields, southwestern grassland cienegas, woody draws, and sites disturbed by thermal pollution or mining.
2. Restore the productive capacity of wetland forests by "improving" the species complement. This element refers to sites that presently are wetlands but with a species composition that is suboptimal (e.g., bottomland sites in the Mississippi Delta that were high-graded, leaving poorer quality species and reduced biodiversity). Many cutover or mismanaged areas are not meeting their full potential as a functioning wetland. Additionally, thousands of acres in the delta region alone are being revegetated through the CRP program, often without full recognition of wetland site characteristics. Research would include an understanding of the sustainability and productivity of the systems in terms of hydrology and vegetation.
3. Develop regeneration methods for wetland systems. Wetland ecosystems have many unique plant species where little or nothing is known about their reproductive or regenerative potential (e.g., filter strip species and Atlantic white cedar). Research will be needed to determine if regeneration can occur naturally or if some manipulation is required. For example, since seed or vegetative material is available, many high-mountain meadows will revegetate naturally if the disturbance factor is removed.
4. Identification of "keystone" species that can influence the success or failure of restoration or creation. Studies should include how these species function through wetland succession. Species such as white-tailed deer can devastate attempts to restore an ecosystem to Atlantic or Northern white cedar. Some species may indicate that the system is functioning as it should.
5. Evaluation of mitigation and restoration success. Consideration should be given to both the biology and hydrology, through monitoring, and the policy needs. Included in this element is research which can describe when a wetland is fully restored. Baseline information to determine functions and processes consistent with "fully restored" is necessary. The cost-benefit analysis of restoration also is of high priority; that is, when does the incremental cost of further restoration exceed the biological or sociological benefit?

MANAGEMENT OF THE WETLAND RESOURCE

What are the impacts of current management practices on wetland functions and values? Are there alternative practices? Important keywords here are long-term management philosophy, Best Management Practices (BMPs), forested wetlands, riparian areas, grazing (livestock and big game), anadromous fish, pests.

Important research topics are:

1. Influence of livestock grazing and domestic foraging on patterns of vertebrate abundance in riparian wetlands. Research would include considerations of plant and animal diversity. Regionally specific issues include big-game species (elk, sheep) in the West, feral pigs in South, and native species in the North-central region.

2. Effects of alternative management practices on wetland ecosystems. A major question is what practices can be used to increase or maintain productivity? Wildlife, fisheries, timber, and recreation are all important endpoints of alternative management.
3. Management of habitats to maintain biological diversity. Wetland ecosystems are critical habitats for migratory birds, including neotropical species. In addition, riparian and other wetlands, such as green tree reservoirs, are important refugia for threatened, endangered, and sensitive species.
4. Establish guidelines for management decisions to control insect or disease impacts on wetland community structure. The fruit tree leaf roller on baldcypress and the willow borer in the West are pests which significantly alter wetland community structure, and therefore, impact management success.
5. Develop low impact harvesting and transportation methods for use in wetland ecosystems. Some methods (e.g., chunk roads) are already used in fragile environments. However, increased demand by the public and by land managers for appropriate technology makes the integration of this type of research essential. Consideration should also be given to the fate of pesticides and herbicides in wetlands, either when used in the wetland system or in the surrounding landscape.
6. Develop the information necessary for BMPs in land management operations, and evaluate their implementation. Issues of particular concern are drainage operations, harvesting impacts, road building, monospecies regeneration, and current engineering methods.
7. Evaluate the impact of public use (e.g., recreation), developmental pressures, including urbanization, on wetland functions. Uncertainties exist in whether the integrity of wetlands can be maintained at the urban interface. Of interest in several parts of the country is the use of forested wetlands on or near National Forests as a disposal site for sewage and waste water; impacts on the wetland functions are not understood.

SOCIOECONOMIC VALUES OF WETLANDS

Can an economic value be ascribed to both commodity and noncommodity functions? What are society's expectations regarding wetland functions? Important keywords here are costs of protection, legal research, timber supply impacts, market vs. nonmarket (cultural) values, diffuse recreation, valuation determines management strategies.

Important research topics are:

1. Valuation of the different functions or components of wetlands. Efforts should identify the individual components (e.g., recreation, wildlife, timber, spiritual values) and for whom are they important. This valuation is not limited to assigning a dollar value, but is essential to make informed management decisions.
2. Determine impacts of changing wetland regulations on timber supply. Landowners are thought to be changing management practices, and therefore harvesting patterns, due to regulatory restrictions. This trend has not been brought into supply analyses (e.g., Southwide Resource Analysis).
3. Cost-benefit and distribution of wetlands protection and management. The intent is to better determine "who gains and who pays?" — although this does not necessarily mean that a dollar value is applied.
4. Evaluate the cost of implementing BMPs. Landowners and managers need the tools to be able to evaluate available BMPs. This must include an assessment of the financial cost, whether the management objective is recreational, timber, or water quality protection.
5. Analysis of legislation or regulation for impacts on land management decisions. Are public or private landowners changing their practices? This issue is especially critical as the various states draft their own legislation, as the Clean Water Act is up for

reauthorization, and as the Federal government determines which bill(s) to support.

LANDSCAPE-SCALE LINKAGES

What is the role of wetlands as an interface between uplands and water? How important are wetlands as a feature on the landscape? Important key words here are large temporal and spatial scales, biological diversity, temporary refugia for species, wildlife-livestock interactions, qualitative changes of habitat and wildlife, cumulative effects, filter strips and land-use, estuarine environments and anadromous fisheries.

Important research topics are:

1. Effects of land-use patterns on wetland occurrence and functions. A better understanding is needed of the role of wetlands as "sinks" for different landscape features, such as chemicals or even wildlife. Important in this element is a consideration of the wetland/agriculture or wetland/ urban interface.
2. Influence of landscape characteristics on the suitability of wetlands for wildlife. Characteristics would include, but are not limited to, topography and connectedness.
3. Influence of landscape characteristics on hydrology and water quality.
4. Evaluation of the contribution of wetlands to the biological diversity across the landscape.
5. Role of wetlands as interface between upland and water systems. On a landscape scale, this effort would include the position of riparian wetlands as buffer strips and their mitigating effect on nonpoint pollution. This element can be extended to consider the position of estuarine systems as an interface between upland and marine environments.

CRITERIA FOR PRIORITIZATION

Priority setting must be done at two levels — at the Washington Office (WO) and at the stations. At the station level, local concerns must be matched against operating funds and the scientific capability of staff and cooperators. WO prioritization must recognize the often conflicting needs of different regions. In making these decisions, the following criteria should be considered.

- Management/Research needs—National Forest Systems; State and Private Forestry; public and private land managers; RPA; Strategic Plans.
- Science Issues—knowledge gaps; scientific validity.
- Operational Capabilities—current research capabilities; time to completion; probability of success.
- Politics/Policy Issues—includes public benefits.
- Cost—budget limitations; marginal costs vs. marginal benefits.
- Inherent Resource Value
- Coordination/Cooperation with other Programs—within FS and externally.

Multiple-Use Values of Forested Wetlands–Policy and Management Implications

John R. Toliver[1]

Abstract.--Applying "normal silvicultural activities" through state-of-the-art "Best Management Practices (BMPs)" is crucial to maintaining and enhancing the multiple-use benefits and values of forested wetlands. The 1977 Clean Water Act (CWA) permitting normal silvicultural activities or practices in forested wetlands allows managers the opportunity to manage these wetlands for values such as timber, wildlife habitat and clean water. Silvicultural practices and how they can be used to maintain or enhance the multiple-use benefits of forested wetlands are addressed as they are interpreted as "normal silvicultural exemptions" by the U.S. Army Corps of Engineers and as they relate to BMPs in wetland and bottomland forests.

INTRODUCTION

Wetlands are "those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances, do support a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands generally include swamps, marshes, bogs and similar areas" (Federal Interagency Committee for Wetland Delineation 1989).

As of the mid-1980's, an estimated 104 million acres of wetlands remained in the lower 48 states, a 53-percent decrease since the birth of our nation (Dahl 1990). This alarming rate of loss, mostly due to drainage and conversion for other human uses, has led to a public awareness of the need to stem wetland losses, protect and properly manage the remaining critical habitats, and, when possible, restore wetlands to or near to their natural state.

Freshwater forested wetlands make up slightly less than half of the remaining wetland acreage (52 million acres) (Dahl et al. 1991). Cowardin et al. (1979) define the Class Forested Wetland as: "characterized by woody vegetation that is six meters tall or taller. All water regimes are included except subtidal. Forested wetlands are most common in the eastern United States and in those sections of the West where moisture is relatively abundant, particularly along rivers and in the mountains. They occur only in the Palustrine and Estuarine Systems and normally possess an overstory of trees, an understory of young trees or shrubs, and a herbaceous layer. Forested wetlands in the Estuarine System, which include the mangrove forests of Florida, Puerto Rico, and the Virgin Islands, are known by such names as swamps, hammocks, heads, and bottoms. These names often occur in combination with species names or plant associations, such as cedar swamp or bottomland hardwoods."

Wetland forests are widely distributed throughout the nation, encompassing coniferous wetland forests with evergreen cover and deciduous wetland forests. The South contains a large proportion of the remaining forested wetlands in the continental U.S., primarily in bottomland hardwoods, cypress swamps, pocosins, and coastal plain pine sites. Although they still constitute some of the largest remaining contiguous wetland habitats in the conterminous United States, these bottomland forests are highly fragmented. Draining and clearing land for agricultural development, flood control projects and intensive forestry are responsible for much of this reduction (Council on Environmental Quality 1989). Fragmentation has had

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a detrimental effect on the remaining and adjacent ecosystems and should be viewed from a landscape or regional aspect as well as from the site or stand level. Loss of critical wildlife habitat, natural flood storage capacity, timber production, recreational opportunity, and poor downstream water quality are among the frequently cited impacts. Loss and degradation of wetland forests and the values associated with them are of concern throughout the Nation.

WETLAND FOREST VALUES

Wetland forests areas are unique ecosystems strongly influenced by water. They usually occur in floodplains or low-land areas near a creek, stream, river, or lake, making them highly attractive to people. Water is essential to plant and animal life and its quality and availability dictate the diversity and quality of the environment. When, how long, how fast, and how much water flows through wetland ecosystems greatly influences their function, value and management.

Streambank forests control soil erosion and provide buffers which improve water quality by filtering soil sediment, nutrients and pollutants. They are extremely important for providing quality drinking water and clean water for aquatic life. Forested wetlands slow floodwater by acting as holding areas and sinks, protecting downstream developments.

Plant life is highly diverse and productive on most wetland forest due to the greater availability of water and nutrients. Slight changes in elevation create many micro-sites where diversity of trees and plants flourish. These sites are often our most productive for flora and fauna. Swamps and sites with slow moving or standing stagnant water are less diverse and productive than streamside forests, but still provide a unique habitat for many species.

Wildlife and aquatic species respond to the diversity of water quality and plant species which provide a variety of food and cover. For example, wetlands, which constitute 5 percent of the total land area of the lower states, sustain 35 percent of our nations threatened and endangered species and provide breeding and wintering grounds for waterfowl, and other migrant birds. Riparian areas, which often include or are adjacent to wetlands, comprise only 1 percent of our western lands, but are the most important or essential habitat for 70-80 percent of the wildlife species. In addition, they are valuable for livestock grazing.

From fast-flowing mountain streams to rivers and sluggish southern bayous, the associated fisheries range from cold-water to warm-water species. Shallow waters created by the rise and fall of floodwater on wetland forests are highly utilized for nursery and feeding grounds. The diversity of water and plant and animal life is a major attraction for recreational hunting, fishing, bird-watching, boating, sightseeing, and many other activities unique to forested wetlands and associated riparian areas.

Ease of access and the availability of high-quality timber has often made forested wetlands in the U.S. vulnerable to poor management practices such as selective logging or high-grading, with little regard for regenerating the valuable timber and wildlife species. These practices as well as overgrazing have often led to degrading the composition and quality of the trees, plant species, and fauna on them. Thus, the present diversity and productivity of many wetland forests seldom represents their potential for producing timber, wildlife habitat, or forage. For example, many wetland bottomland hardwood sites in the south are stocked with less than 3000 board feet of sawtimber of less desirable species such as maples, elms, and gums. If properly stocked and managed, they could easily carry 6000 to 10,000 or more board feet of red and white oaks, ashes, and a diversity of other species, providing a profitable harvest every 8-10 years and as well as mast bearing species for wildlife. Through proper management practices, we can protect and maintain, or rehabilitate and restore, the productivity and carrying capacity of the remaining resource.

NORMAL SILVICULTURAL PRACTICES AND BMPS: THE FORESTED WETLANDS MANAGEMENT ISSUE

In 1972, U.S. Congress passed amendments to the Federal Water Pollution Control Act (FWPCA), also known as the Clean Water Act. Under this act the waters of the nation were to be regulated. These amendments were designed to establish water quality control goals and to protect wetlands from unwarranted human disruption. A review of the development of FWPCA regulations and current interpreta-

tions is presented by Cubbage et al. (1990). Section 404 of the act states that any activities that deposit dredged or fill material in the nation's waters or wetlands will be subject to regulation by the Army Corps of Engineers (COE), with over-sight by the U.S. Environmental Protection Agency (EPA).

In 1977 amendments to the FWPCA exempted "normal silvicultural activities" from permit requirement including construction and maintenance of temporary logging roads when "accomplished in accordance with approved Best Management Practices (BMPs)" (Cubbage et al. 1990). BMPs are: "Methods, measures, or practices applied to prevent or reduce water pollution, including, but not limited to, structural and nonstructural controls and operation and maintenance procedures. Usually, BMPs are applied as a system of practices rather than a single practice. BMPs are selected on the basis of site-specific conditions that reflect natural background conditions and political, social, economic, and technical feasibility" (McLaughlin and Holcomb 1991). Cubbage et al. (1990) present a more liberal interpretation of BMPs to include those management practices recommended to prevent or minimize environmental damage, such as erosion, water pollution, fish or wildlife habitat destruction, or soil productivity losses. This interpretation is probably more along the lines of what the general public interprets as BMPs. Specific BMPs are not defined by the COE or EPA, but most states have BMP manuals which have generally been developed by committees composed of industry, state, federal, and academic forestry professionals.

Much controversy remains as to what constitutes the "normal" silvicultural activities which are exempted. In addition, there is considerable variation among states relative to enforcement of voluntary BMPs. The question of what are "normal silvicultural activities" and the need for forest managers and land owners to voluntarily use approved BMPs will guide the future of forest management and silvicultural practices in wetland forests.

McLaughlin (1991) states that "normal silviculture is the plowing, seeding, cultivating, minor drainage, harvesting and the construction of temporary roads, skid trails, landings and the maintenance of temporary and permanent roads using State BMPs." Minor drainage does include bedding, at least as usually practiced on the forests in the Southern Region. McLaughlin (1991) believes that after considering normal silvicultural exemptions, the only activities on most National Forests subject to Section 404 are permanent road construction/reconstruction; recreation sites; mineral, gas and oil exploration and development; fisheries and wildlife; soil and water; and special uses. He estimates that, with the silvicultural exemptions and nationwide permits, 95 percent of the activities occurring on district wetlands, riparian areas, and floodplains do not need individual permits. However, his rule of thumb is: "WHEN IN DOUBT, CHECK IT OUT."

According to the COE, Vicksburg District (1991), "Normal Silvicultural Activities embraces those activities associated with planting, cultivation, minor drainage, and harvesting of forest crops that are generally accepted as state-of-the-art procedures for tending and reproducing forest crops." Following are some generalized facts related to normal silvicultural activities as presented by the COE, Vicksburg District (1991) to the Capitol Chapter of the Mississippi Society of American Foresters:

1. An established silviculture operation is any operation that has as its primary purpose the production, harvesting and reproduction of forest crops. If at any time it becomes apparent that harvesting will not be followed by continued regeneration of forest crops on the wetland, the operation will cease to be considered an ongoing silviculture operation, and discharges of dredged and fill material associated with the harvesting will be regulated.
2. It should be recognized that the COE is regulating land clearing when the work occurs in waters of the U.S. It has been determined that land clearing and site preparation for the purpose of replanting native wetland timber species is exempt as a normal silvicultural activity. A silvicultural crop must be planted within three years of the time the site was prepared for planting in order to qualify for the exemption. Any activity related to the gradual or immediate conversion from the production of forest crops to the production of agricultural crops or other upland endeavors is not considered "normal silviculture."
3. The removal of surface water is normally only a temporary measure to facilitate harvesting, and there is no need to main-

tain ditches constructed for that purpose. Once harvesting has been completed, ditches should be plugged to restore the hydrologic regime that existed prior to the harvest. Ditching to facilitate the planting of upland forest crops in wetlands is not exempt.

4. Ditching for the purpose of removing surface water that has been impounded as a result of beaver activity or changes in drainage patterns resulting from sediment deposited during flooding is considered exempt in all cases where it is apparent that such changes in the hydrologic regime have taken place. If the estimated age of the emergent wetland vegetation resulting from the blockage is 3 to 5 years or more, this exemption will not be deemed applicable.
5. Removal of blockages does not include enlarging or extending the dimensions of, or changing the bottom elevations of the affected drainage way as it existed prior to the formation of the blockage, such that the use of the land in question can be changed.
6. Maintenance of drainage ditches is considered to be the same as the removal of blockages. If maintenance is neglected to the point that the wetland vegetation which emerges as a result of the blockage is estimated to be 3 to 5 years old, the ditch will be considered new construction.
7. As long as maintenance is confined to the original cross-section of the ditch and is conducted within the above time constraints, it is exempt. It should be pointed out that this does not apply to natural streams which are identified as waters of the United States.
8. Road construction is not usually a problem. The width, alignment, and composition of the road has no bearing on the exemption unless it is obvious that BMPs have been neglected or that the road is serving a function other than the conveyance of vehicles, (i.e., a continuous roadside borrow ditch used to drain adjacent wetlands when it should only function to maintain a dry roadbed).
9. Prior notification is not required before undertaking an exempt activity. However, it is best to notify the COE of any intent to initiate major activities such as road construction, land clearing, and site preparation especially when such activities are highly visible to the general public. These facts do not cover all situations. The best rule of thumb is still: "When in doubt, check it out."

OUR CHALLENGE

As practicing silviculturists, forest managers, research scientists, and administrators, we must play an important role in the future of silviculture in wetland forests. The official policy of the EPA and the President is one of no net loss in wetlands area in the United States. Eugene Odum (1978) stated: "Riparian zones have their greatest value as buffers and filters between man's urban and agricultural development and his most vital life-support resource-- water. Preservation based on public riparian rights provide an effective hedge against overdevelopment of urban sprawl and agricultural or forest monoculture."

I think one can safely say that in the public's eye this statement can be extended to include all wetlands. Even though they may be physiographically distinct, forested riparian zones and wetlands often cannot be dealt with as separate functional entities and are best evaluated and managed as parts of larger landscape units. Forested wetlands are highly productive, highly diverse, and dynamic natural environments. As stewards of our nation's forests, we must insure that we follow approved BMPs to maintain, enhance, and if possible restore wetland forests. To do otherwise could mean loss of these highly productive multiple resource sites, either outright or to preservation.

If it is up to practicing forest managers to use normal silvicultural practices and follow BMPs and research scientists are responsible for determining state-of-the-art BMPs. This must be an evolutionary process. Research must constantly strive to stay ahead of the resource needs and determine the positive and negative impacts forest management practices have on the wetland forest ecosystem, including all flora and fauna. We all must demonstrate to the public that wetland forests can be managed for multiple resource use without loss or degradation of the habitat, and that proper silvicultural and management practices can in

fact be used to enhance and restore their values. Here is where Forest Service Research, State and Private Forestry and National Forest System personnel must work together.

WHERE THE FOREST SERVICE IS ON WETLANDS

National Forest managers have specific responsibilities for managing wetlands, riparian areas, and floodplains. These responsibilities are outlined in Executive Orders for Wetland Protection and Floodplain Management and in Section 404 of the Clean Water Act. The Forest Service (FS) must comply with the requirements, standards and procedures of the Clean Water Act as must any private citizen or corporation. The FS meets these responsibilities through using specific standards and guidelines and BMPs for multiple use. The management requirements for wetlands, riparian areas, and floodplains should begin in the Forest Land Resource Management Plan and extend into compartment prescriptions, stipulations for special use permits, land conveyance documents, project plans, NEPA documents, and contract clauses (McLaughlin 1991).

The Southern Region's policy for wetland, riparian area, and floodplain management has three cornerstones (McLaughlin 1991). "First, we support an aggressive approach to the protection and management of wetlands, riparian areas, and floodplains. We achieve our goals for protection and management through ecosystem management. We have prepared a Riparian Area and Wetland Management Strategy, approved by the Regional Forester. This strategy will be implemented through our Forest Land Resource Management Planning and implementation process. Second, the delineation and management of these areas require an interdisciplinary approach. Disciplines needed are silviculture, plant ecology, hydrology, soils, fisheries, and wildlife. Other disciplines that we use on a case-by-case basis are hydrogeology, geology/minerals, engineering, archeology, and landscape architecture. Third, we implement our wetland, riparian area, and floodplain management through cooperation and monitoring. We cooperate with states, universities, FS research scientists and others in developing BMPs and in conducting monitoring and training." All Regions need to take a similar approach.

Wetlands are a priority issue in the Nation and the FS has recently taken the lead to bring together all parties involved from a regulatory, research and resource managerial viewpoint. We must all strive to better understand the values and functions of wetlands ecosystems such that we can managed them for the best benefit of mankind.

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Management Issues In Forested Wetlands

Jeffrey L. Vowell[1]

Abstract.--Management issues involving forested wetlands are largely centered around balancing utilization of the timber resource with other wetland functions and values. Because of the nature of timber harvesting activities, forest management issues concerning Streamside Management Zones, Bedding, Wetland Conversion and Wet Weather Operations are complex and often controversial. These issues are examined and discussed along with associated regulations, where applicable.

INTRODUCTION

Few today would disagree that forested wetlands have important functions and values. However, the question often faced by the forestry community is: How can we protect these functions and values?

From a preservation point of view, the answer to that question is relatively simple - don't do anything to disrupt the natural processes that characterize forested wetlands. However, if we continue to manage wetland forests for wood and wood products (which society demands) then there is necessarily going to be some compromise of values - at least in the short term.

From a forest management perspective, the answer to the previous question is much more complex and inherently controversial. One major reason is because the term "management" almost always includes some level of timber harvesting. In order to conduct harvesting activities, we normally have to build roads. During road construction we often have to cross big streams and dig ditches. If we are responsible in our management planning, timber harvesting is followed by some effort to reforest the site. Reforestation may involve site preparation and/or tree planting and may include fertilizer or chemical application. In some wetlands minor drainage may be necessary to facilitate heavy equipment operation. All of these activities, common to forestry, are part of the management of forested wetlands, and any given activity may have the potential to diminish some wetland values.

In the past, forest managers have approached most "forestry-environmental" issues almost exclusively from a water quality perspective. The establishment of forestry Best Management Practices (BMPs), for example, was a water quality initiative. However, as we develop a greater understanding and appreciation of other wetland values, we are finding that in many cases traditional BMPs, oriented to water quality, do not address the protection of these other values. In fact, accommodating one wetland value through the use of BMPs may actually compromise some other value.

The implementation of management activities in forested wetlands along with strategies to protect wetland values causes foresters to encounter a number of important management issues. The following is a discussion of several common management issues associated with forested wetlands.

STREAMSIDE MANAGEMENT ZONES

Traditionally, Streamside Management Zones (SMZs) are corridors provided along surface waters, for which special management criteria has been established to protect water quality. Generally, the width and management of SMZs is designed to minimize such things as sediment input, extreme temperature fluctuations and streambank or instream erosion.

Through BMP programs, most states have established management criteria without contributing to water quality degradation. For wetlands adjacent to

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streams and lakes, these management criteria have obvious application. For other types of wetlands, however, they may not. For example, how does a SMZ apply to a cypress pond?

Isolated wetlands such as cypress ponds, as well as flowing wetlands with poorly defined or undefined channels, may not always lend themselves well to the traditional SMZ concept. Protecting wetland values in these type systems may necessitate more non-traditional BMPs. This is an important management issue for certain types of forested wetlands.

In addition to water quality, another management issue associated with SMZs is flood control or flood damage abatement. Flood control is an important value often attributed to wetlands and raises an important question about SMZs. Specifically, is it better to have harvesting in the SMZ or should there be "non-management" or no-cut zones?

We know that trees, other vegetation and associated ground cover in riparian areas help ameliorate floodwaters by reducing stormflow velocities which, in turn, provides water quality benefits, via sediment deposition. But how effective is a relatively small (narrow) SMZ in a large expansive river floodplain? In terms of a filter strip or sediment buffer, the SMZ was originally designed to intercept water moving toward the stream from the hillslope. However, in large river floodplains water is commonly moving away from the stream (during flood flows) and into the adjacent forested areas.

A recent study in a large river swamp in Alabama (Aust et al. 1991) found that clearcut areas actually trapped more sediment than uncut areas due to the stumps (30-60 cm high) and logging slash on site. The "harvested condition" apparently provided more resistance to flow and lower velocities, thus contributing to both the flood control and water quality values in that wetland system. In this study the timber harvesting or management of the wetland forest was compatible with maintaining the flood control values as well as water quality benefits.

In other types of wetland logging, however, this may not be the case. The study of cypress logging and regeneration (Ewel et al. 1989) suggest that harvesting which leaves high stumps (maximum flood control value) may provide significantly less potential for stump sprouting compared to low-cut stumps. Since most cypress reforestation is by root and/or stump sprouting, stump height is certainly an important consideration for regeneration purposes.

In addition, wetland logging in the Southeast is often conducted with mechanized equipment. Most common is the fellerbuncher (with a shear) which cuts the trees and stacks them for pick up by the skidder. The trees are then brought to the loading area where they are topped and limbed, thus removing the slash from logged area. This harvesting method results in a "clean site" with relatively low-cut stumps, and optimizes regeneration for shade intolerant species like cypress. However, this method may lessen the flood control and water quality protection value of the wetland for some time.

Depending on the type of wetland, management objective, method of harvest and the type of harvesting equipment used, there may be important tradeoffs between maximizing regeneration potential and maximizing flood control and sediment entrapment capability, or other wetland values. Form a management perspective, those are important forested wetland issues to resolve.

BEDDING

Another important management issue regarding forested wetlands has to do with a site preparation technique called bedding. The purpose of this practice is to provide an elevated soil bed for pine seedlings in the event the area experiences a high water table for an extended period of time. Under section 404 of the Federal Clean Water Act, the placement of soil beds, as well as other normal silvicultural activities, is exempt from the permitting process as long as the activities do not result in conversion of the wetland to an upland, or "reduce the reach or impair the flow and circulation of waters of the U.S." (U.S. Department of Defense 1986).

The traditional BMP for virtually all mechanical site preparation is to conduct such operations "on the contour", i.e., so that bedding furrows or other soil surface alterations do not act as channels for stormflow. As with most BMPs this methodology principally has a water quality objective - to prevent erosion and sedimentation. However, if beds are placed on the contour, there is a question of whether or not the beds may in fact act to reduce the reach or impair the flow and circulation of waters of the U.S., and thereby require a 404 permit.

Conversely, if beds are placed perpendicular to the contour, there is a concern that bedding may concentrate surface waters and act as conveyance, potentially

resulting in widespread erosion, drainage and possibly conversion of the wetland to an upland. Since bedding is necessary for reforestation on many forested wetland acres, such as pine flatwoods, the bedding issue is a critical management issue to resolve.

CONVERSION

Whether or not forestry activities (such as bedding) actually result in conversion of wetlands, is usually a question of drainage. Drainage is certainly a key management issue in forestry. Again referring to the federal regulations - minor drainage is expressly exempt from 404 permitting and clearly considered not to constitute conversion. However, there is no clear criteria that distinguishes between minor drainage and the level of drainage that does constitute conversion.

Under 404, minor drainage does not allow drainage associated with the immediate or gradual conversion of a wetland to a non wetland, or the construction of any canal, ditch, etc. which drains or otherwise significantly modifies a steam, lake, swamp, etc. Unfortunately, much of the terminology such as "significantly modifies" is often difficult to define and generally leave much to interpretation.

In Florida, State regulatory agencies have addressed minor drainage for silviculture by establishing specific criteria for such things as ditch spacing, cross-sectional area and maintenance. In addition, for canals which were constructed years ago, the forestry community is developing special BMPs that deal with canal maintenance, canal crossings, and surface drainage into canals from adjacent areas.

However, there is still considerable debate concerning the issue of forestry and wetland conversion, which continues to cause confusion and misconceptions about management of forested wetlands. In some cases, a change in management intensity or forest species composition may be considered to constitute conversion of wetlands. In other cases, depending on wetland type, the same changes may be considered exempt from 404 permitting and acceptable management practices. Resolving the issue of "what is conversion" is crucial to providing forest managers with the tools necessary for appropriate decision making.

WET WEATHER OPERATORS

The last management issue for discussion here asks the question: When is a site too wet for certain forestry activities? While this may seem like a relatively simple question, the answer is quite complex when trying to establish criteria for making management decision.

The issue of "wet sites" primarily involves three problems: (1) rutting (which can promote drainage); (2) soil compaction (which can reduce natural regeneration); and (3) the potential for degradation of water quality. Forest managers often need to determine what conditions constitute "too wet", when are skidder ruts "too deep", and at what point does soil compaction become "too great"?

Answering these questions, becomes even more complex when considering the many different types of forested wetlands, and the soils and water resource features associated with each one. For example, appropriate management criteria should take into account the fundamental differences between alluvial river floodplains with mineral soils and isolated cypress ponds with organic soils - strategies for protecting wetland values on one type may not be suitable for another.

Since the soil/water regime of forested wetlands often dictates the potential for adverse impacts, establishing reasonable criteria for identifying problem conditions is an extremely important management issue to resolve.

SUMMARY

In closing, it is important to point out that the management issues mentioned here certainly are not all that foresters must deal with when managing forested wetlands. However, these issues do constitute a large part of the current controversies surrounding the management and utilization of wetland forests. The challenge to forestry professionals in resource regulation, management and in particular research, is to develop solutions to these issues and provide clear and concise management criteria to the extent possible.

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Watershed Rehabilitation: A Program for Lake Tahoe

Albert H. Todd[1]

Abstract.--Watershed rehabilitation has been recognized as a critical element in the programs needed to improve the quality of Lake Tahoe's waters. Erosion control and restoration needs in the Lake Tahoe Basin have been estimated at over $300 million on urban and forest lands. The Forest Service developed a comprehensive watershed rehabilitation program for forest lands approximately 12 years ago and has completed projects on over 3000 acres of disturbed slopes and streamzones. The program includes holistic watershed problem inventories, cooperative fisheries/streamzone rehabilitation projects, retrofit of forest facilities and roads, harsh site revegetation, KV and mitigation projects, and erosion control monitoring. Program success stems from institutionalizing the Forest commitment to watershed rehabilitation in the Forest Plan and budget process and continuing to keep partners and support groups informed and involved.

INTRODUCTION

Lake Tahoe was known to little more than the Paiute and Washoe Indians prior to its discovery in 1844 by General Fremont. This spectacular lake on the rugged border of California and Nevada is renowned for its remarkable clarity and great depth and is one of the largest and purest alpine lakes in the world. Because of its beautiful setting and ability to provide year round recreation, pressure from residential and commercial development has been enormous. Much of the past development occurred without an understanding of the environmental consequences. Past damage along with the current impact of 25 million visitors each year, has drastically changed the Basin's environment. Destruction of streamzones and wetlands, and disturbance of steep hill slopes have all increased discharges of sediment and nutrients into Lake Tahoe and its tributaries. These changes have brought about a decline in the water quality of the Basin, but most importantly, have reduced the exceptional clarity of Lake Tahoe itself. Once transparent to a depth of over 120 feet, Lake Tahoe's clarity has been reduced over 23 feet in 20 years (Figure 1).

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Lake Tahoe's Unique Characteristics

The combination of altitude, granitic geology, climate and relatively small drainage area have created an oligotrophic lake with very low biological productivity and crystal clear waters. Few nutrients are naturally available to "fertilize the lake" making Lake Tahoe's waters extremely sensitive to sediments and nutrients carried into the Lake by erosion and runoff. Once in the Lake these "pollutants" may be retained for as long as 700 years owing to its enormous volume (Byron and Goldman 1986). At Lake Tahoe, the integrity of the land greatly influences the quality of the water. Most soils have low fertility and high erosion rates when disturbed. These factors coupled with a short, dry growing season create difficult and unique erosion control challenges.

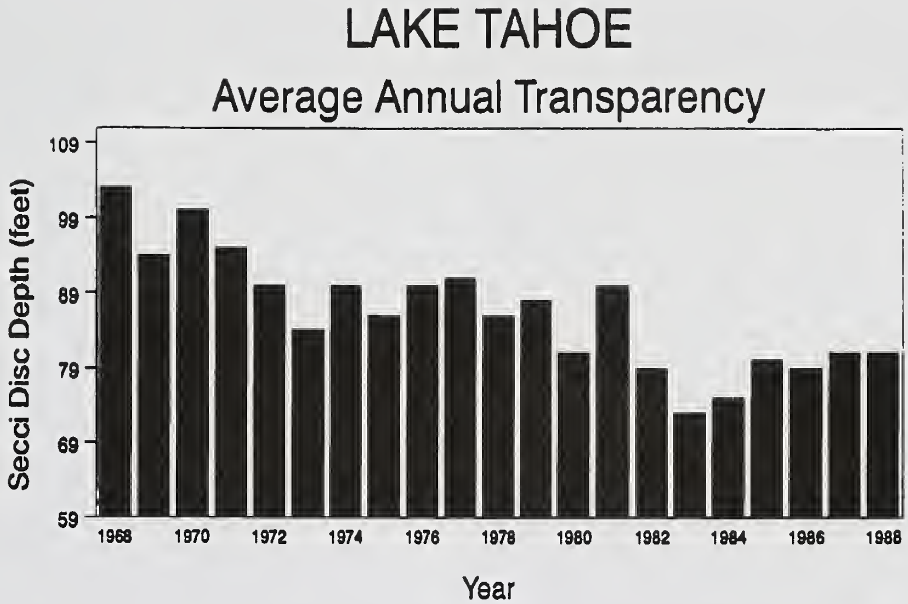

Figure 1. Long-term trend for decline in Lake Tahoe water clarity.

Forest Service Watershed Rehabilitation Program

It was to help protect this national treasure- Lake Tahoe -that the Lake Tahoe Basin Management Unit (LTBMU) of the USDA Forest Service (FS) was created in 1973 and Congress in 1980 began authorizing federal acquisition of sensitive lands and made a commitment to funding erosion control and watershed improvements. The FS manages over 75 percent of the land within Tahoe's watershed boundary. Over 40,000 acres have been purchased over the past thirty years. Many of these lands were disturbed and had serious erosion problems. The FS has initiated several programs which play a significant role in the effort to reverse past damage to Tahoe's watersheds. A watershed restoration program focuses on the improvement of watershed conditions on public lands with an emphasis on streamzones and wetlands. An erosion control grants program provides financial assistance to local governments for improvements in the urbanized portion of the Basin. Over $15 million has been invested in this effort to date. These programs are an essential part of an interagency erosion control program which intends to spend over $300 million over the next 20 years to correct mistakes of the past. The reversal of the Lake's decline in clarity will be in large part due to these erosion control activities. This paper discusses program development and philosophies for public lands in the Lake Tahoe Basin.

PROGRAM PHILOSOPHIES

Development of a comprehensive, well-integrated watershed rehabilitation program takes time and commitment. The success of Lake Tahoe's program is based on using several basic program philosophies as building blocks.

Institutionalize the Need

The first place to start is through recognition in the Forest Plan. The LTBMU plan contains descriptions of watershed rehabilitation goals and predicted future conditions, objectives and estimated annual outputs, management area direction where specific watershed rehabilitation needs are known, and reportable accomplishments expected as part of plan monitoring and evaluation. By integrating these needs into the Forest's base level of operations, it is less likely that rehabilitation will be a "nice-to-do" activity.

The plans of other government agencies provide another forum in which to communicate Forest goals and commitment to the program. At Lake Tahoe, the Forest program is referenced in the Lake Tahoe Water Quality Plan of the Lahontan Water Quality Control Board and is incorporated as a key element of the Tahoe Regional Planning Agency (TRPA) Water Quality Plan. Accomplishments are reported to the TRPA to help them evaluate interim goals of the Captial Improvement and Stream Environment Zone portions of the plan.

Other agencies such as State Fish and Game and local government plans for recreation or natural areas provide other areas for potential integration.

Budget Structure

The greatest difficulty often presented by funding for rehabilitation work is that it is added on to a Forest's annual program and timing can prevent adequate advance planning or ability to focus personnel on a given project. To be effective in the long term in carrying out a stable program of watershed rehabilitation, Resource Officers and Forest Hydrologists or and Soil Scientists must work hard to build a portion of the program each year within constrained budget levels. Preferably, this must occur at budget planning levels 1 or 2 to guarantee success. Funding stability allows the Forest to focus personnel on rehabilitation planning and implementation on an annual basis. In this way, the earth scientist is not "taken away" from other duties to complete watershed rehabilitation but rather it is planned as part of the annual program.

Figure 2 illustrates the steady growth in commitment to the LTBMU program at Level 2. The last column represents the level needed to accomplish all work as prescribed in the Forest Plan.

Build and Maintain a Support Base

This building block is essential. Without internal and external support networks for a watershed rehabilitation program, it is likely to have little chance for growth. However, support must be built around a program that is well-defined. A good first step is to create a program document which communicates and illustrates the goals, objectives, actions, needs, and potential accomplishments of such a program. This program description is the tool for communication of the program to the Forest Management Team, Regional Office, and outside agencies and interest groups. The LTBMU completed a general Watershed Improvement Needs (WIN) Inventory in 1987 to illustrate rehabilitation needs in the Forest Plan. This initial document was based on known information and was assumed to be dynamic, and has been updated on 3-5 year intervals. Figure 3 shows the areas of watershed improvement or facility Best Management Practice (BMP) retrofit defined in the initial plan.

To keep interest high, the program should be continually visible through presentations to Forest Management Team meetings, conduct of field trips to rehabilitation sites, preparation of concise and illustrated project reports, presentations to professional

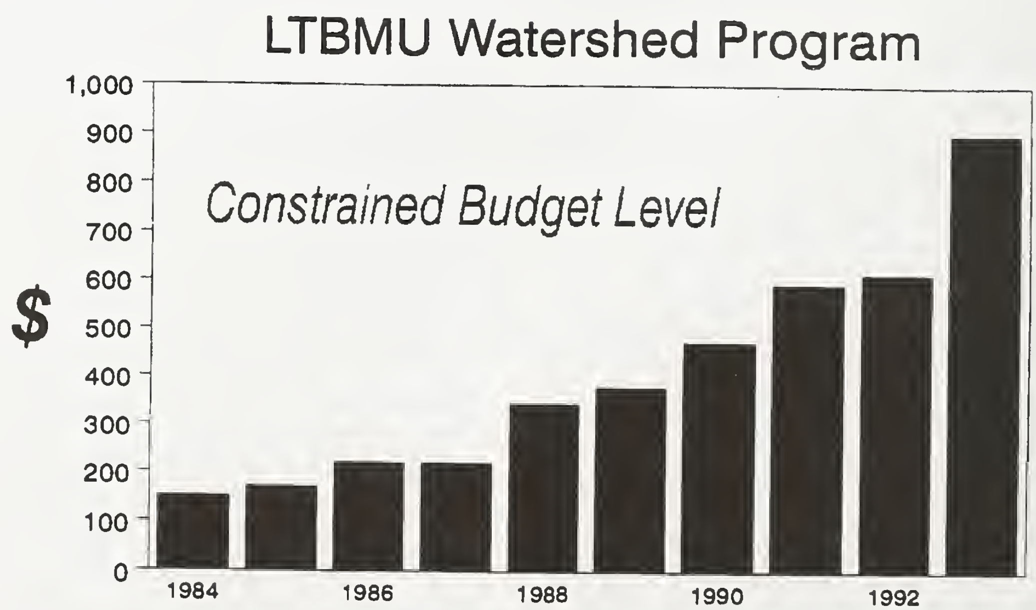

Figure 2. LTBMU Watershed Budget growth reflecting increases in watershed rehabilitation and monitoring program.

Category	Acres	Est. Costs
Lands & SEZ	605	$5,479,051
Roads & Trails	535	$5,228,660
Rec/Adm Sites	232	$ 810,218
Special Uses	548	$4,785,291
Grazing	220	$ 316,800

Figure 3. Watershed Improvement Needs as identified in 1987 LTBMU Forest Plan (USDA Forest Service, 1987).

conferences, local service clubs, and interest groups. Don't underestimate the power that an informal presentation to a school group or service club can have on the politics of future support for watershed programs. When a project is completed, identify it to Forest users as a watershed improvement project by using a simple but well-designed wood or metal sign. If it was a unique or particularly interesting project, add an interpretive description. At Lake Tahoe, we have worked closely with our recreation naturalists to develop ways to communicate watershed projects. The development of volunteer projects or cooperative ventures adds to support and enthusiasm in a local area. Earth scientists need to be involved in interagency or public committees and visible in their local area of influence. There is no better way to do this than through a watershed improvement program.

IMPLEMENTATION PHILOSOPHIES

On the technical/design level, it is also helpful to develop some guiding principles for program implementation. These basic philosophies help focus problem inventory, set project priorities and techniques and designs which will be incorporated in individual projects.

Whole Watershed Inventory

Most watershed problem inventories read like a laundry list of project sites: gullies, streambank, road cut, etc. The LTBMU's initial inventories were no different. However, by looking at project sites independently, interactions with watershed dynamics, public use patterns, other disturbances, and historical influences can be overlooked. Many watershed projects have tried in vain to cure a symptom rather than the true cause of an erosion problem, or falsely identified a natural condition as a problem needing treatment. This is most apparent in stream systems. The interrelated processes that serve to convey water and determine its quality are complex. Erosion problems may be the result of an imbalance not obvious at the site of the problem.

In 1988, the LTBMU began to change its approach to identifying watershed rehabilitation needs and planning erosion control projects. Survey crews inventory 2-10,000 acre watersheds as functional units, compiling all known information about hydrology, soils, fisheries, historical and current land uses, and future management. Field inventories quantify stream types, channel stability, as well as documenting all observed erosion problems. An attempt is made to attribute the observed erosion to either a man-made or natural cause and to assess its relative priority. In this holistic approach, watershed rehabilitation projects can be planned as integrated activities with the appropriate land use, coordinated with other resources such as recreation or engineering, and more successful stewardship can be the result. In addition, this approach provides a more meaningful arena in which to conduct meaningful monitoring.

Protection/Prevention

It is no mystery to land managers that public lands are receiving more and more use from visitors each year. In the Lake Tahoe Basin, where over 20 million people visit each year, the pressure on sensitive watershed resources is continually increasing. It is also well known that once disturbed, the sterile soils and harsh climate of Lake Tahoe, make rehabilitation difficult. Understanding these facts, the watershed staff has made protection of lands and prevention of compaction or disturbance a hallmark of its erosion control program. Control of public use by log fencing, designating trails for vehicle or people use, even investing with recreation in improving access has had a significant impact on preventing new problems from appearing on a future project inventory.

Non-Structural vs. Structural Techniques

A very simple concept to implement is the focus on using non-structural approaches to problem-solving whenever possible. These techniques focus on use of revegetation, mulches, bio-technical design, and natural materials. Non-structural techniques re-

duce future replacement and maintenance costs. The state-of-the-art is a mix of old and new, proven conservation practices, and new materials and technology. Project planners must employ imagination and ingenuity in blending these approaches on the ground.

Aesthetics

One rarely sees the words "aesthetic quality" stated in the goals of erosion control or rehabilitation projects. However, implicit in the Lake Tahoe Basin's philosophy is that projects constructed in the natural environment should tend to blend into the landscape as quickly as possible. Forest lands at Lake Tahoe are often intermingled with urban neighborhoods, and communities are increasingly placing high value on the beauty of the landscape. This means that projects are planned in the context of landscape design, use of natural materials, and revegetation with native plants is a priority of watershed rehabilitation projects. With this philosophy in mind, design and construction aim to have the project area incorporate the spatial character, forms, patterns and textures that are found in the natural landscape and avoid rigid lines and uniformity (Todd 1988). Projects may require extra attention to layout, landscaping, and design.

WATERSHED REHABILITATION PROGRAM COMPONENTS

In developing the watershed rehabilitation program at Lake Tahoe, attention was focussed on making it as comprehensive as possible in order to encompass all elements of land use that had a potential to affect water quality or watershed condition. The program needed to be more that just a watershed program, but a Forest program with connections to other functional areas. The LTBMU established five primary program areas which needed attention.

WIN Inventory

The importance of whole watershed inventory has been discussed earlier. The LTBMU set a goal for inventory of all 64 subwatersheds within 10 years. With over one-third of these areas surveyed, the Forest plans to complete all watersheds by 1998 (Figure 4). A summary report of watershed improvement needs, first published in 1986, will be revised

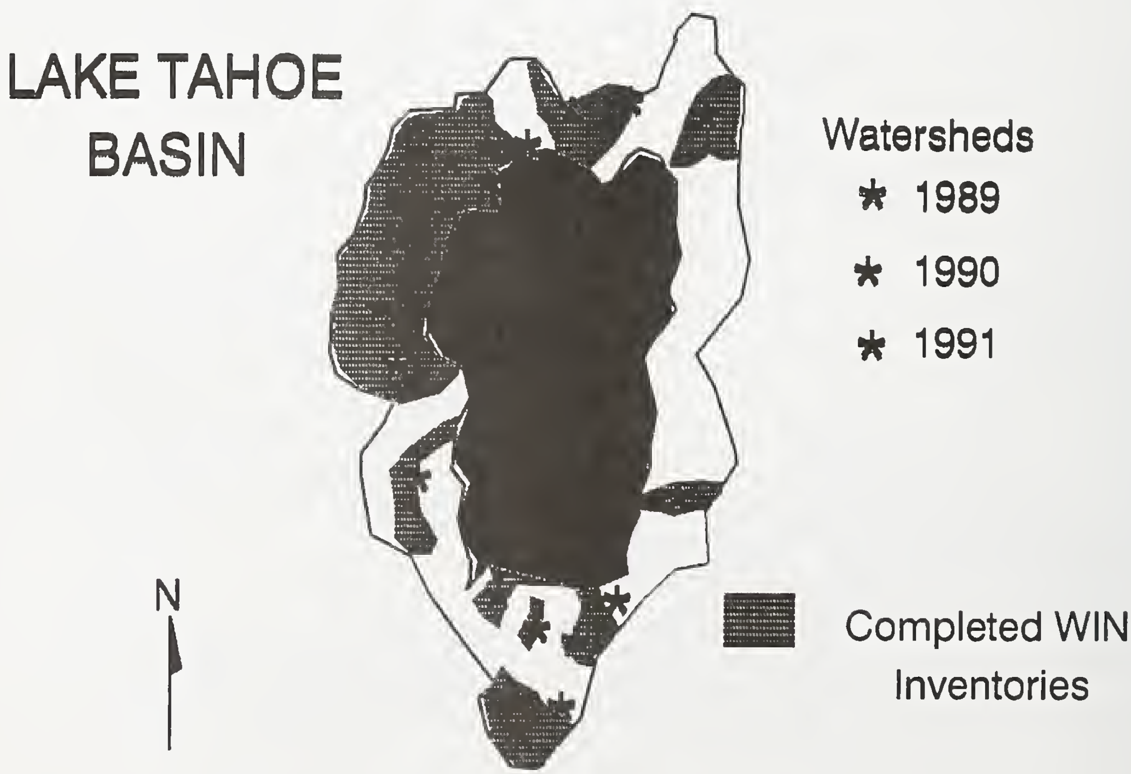

Figure 4. Map showing WIN Inventories conducted to date.

and released again in 1992. The WIN Inventory defines the program and includes rehabilitation needs on forest lands and at facilities and reports accomplishments and monitoring results. For example, the first watershed rehabilitation plan developed for Blackwood Canyon, brought together numerous projects scattered throughout the watershed to have a cumulative effect on long-term water quality and provide a means to work with and enhance nature's own healing processes.

Individual projects dealt with hillslopes, stream channels, major disturbance areas such as a quarry and mill site, roads, trails, and forest management.

Riparian Areas/Fisheries Enhancement

The improvement of riparian condition and rehabilitation of streamzone problems are the highest priority projects on the LTBMU. It is most logical to combine programs with fisheries as most stream rehabilitation projects can be designed to also enhance fish habitat. By combining program objectives, stream surveys, project design, and project funding and implementation, stream improvement projects are more successful. In addition, fish habitat improvement projects have many cooperative partners that can provide more support to furthering watershed rehabilitation goals. WIN Inventory and fish surveys have been coordinated on the LTBMU so that fisheries crews complete stream typing and reach definition and are then followed by watershed survey teams. This standardizes data collection for stream reaches and provides the common basis for planning future projects.

Harsh Site Revegetation

Because of the difficulties experienced in the Lake Tahoe Basin with the revegetation of decomposed granite soils, the LTBMU focussed on harsh site revegetation as a specific program element. This component of the program supports other projects through technology advancement, testing of materials and techniques, and information sharing. Over four years ago, the LTBMU organized a Revegetation Working Group composed of various government, private contractor, and academic representatives to share information and discuss success and failures of various plant materials and techniques. The group remains active and has resulted in the establishment of a thriving native plant nursery at the Nevada Division of Forestry facility in Washoe Valley, a composting and wood fiber diversion project for dryland mulches, and an active program of native seed collection and plant testing.

Federal Facilities Compliance - FFC

The need to rehabilitate FS campgrounds, administrative sites, permittee resorts and facilities, and roads and trails is a major portion of the watershed improvement program at Lake Tahoe. Local regulatory agencies have established stringent standards for the BMP retrofit of these sites and with the FS have set deadlines for their completion. The Lake Tahoe Basin has identified over 50 separate sites requiring retrofit and in nearly all cases the improvements are expensive. The role of the watershed rehabilitation program is to facilitate planning and assist in the future implementation of these retrofit projects. Success in this program requires building a partnership with recreation and engineering personnel and organizing a long term program to address needed improvements. In these cases, funding must be planned years in advance and programmed through multiple funding sources. At the LTBMU, a 10-year program was identified and scheduled.

Permittees also become important team players in this program. Retrofit planning provides a forum within which to discuss other improvements that the permittees may have in mind. Negotiation on this level can provide incentives for permittee action. For example, at the Zephyr Cove Resort, planning to stabilize parking areas and control runoff and people movement led to a million dollar project to develop a master plan for upgrade of the entire resort. To date, the FS and permittee have each invested $300,000 in the project. In another case, by looking at a subwatershed area, Heavenly Valley Ski Area will add snowmaking capabilities, new road access and new lifts while spending almost $3 million over the next three years to stabilize disturbed areas in the same project area.

Urban Lots

Close to half of the National Forest lands within the LTBMU have been acquired through land purchase or exchange since 1950. Many of these lands were purchased to facilitate their rehabilitation. In addition, over 4000 parcels will eventually be purchased as a result of PL 586-96, the Santini-Burton

Act. What makes this unique is that these 4000 parcels are almost entirely 1/4 to 5 acre lots within urban subdivisions or in the urban/wildland interface. These properties present a different kind of erosion control challenge. Close coordination with local governments is necessary to deal with the problems of urban encroachments, destruction of cover, highway and local road rights-of-way, and control of vehicle access. Annual inspections of newly acquired lots are made to assess protection or rehabilitation needs. Lots are then prioritized and scheduled for improvement.

SETTING PRIORITIES

Determining which project or watershed area to work with first can be a complex process. More than one reason may exist that causes a project to rise to the top of the implementation schedule. Watershed staff on the LTBMU use the critera in Figure 5 to establish priorities.

EROSION CONTROL MONITORING

Erosion control activities must be effectively targeted to the source not the symptom of pollutants and evaluated through regular monitoring (Schmidt 1988). However, the complexity of many erosion control problems make rigorous monitoring difficult. The LTBMU has found that monitoring can provide information which improves project design and erosion control techniques, helps prioritize activities, and increases our knowledge of the function and natural recovery processes at work in the natural stream system. Monitoring is also essential to ensuring future monetary and political support of erosion control work and equally important, to help reject activities relying on mitigation which is not effective at reducing the risk of disrupting the watershed system.

Monitoring should be based on questions asked by scientists, managers, politicians, or funding entities, such as: Are erosion control projects effective in improving water quality? What constituents? Is erosion as observed more severe than would be expected from natural processes? How effective is a project at removing sediment and nutrients from spring runoff? Is riprap or vegetation more effective at reducing erosion and runoff on road slopes? Are structural or biotechnical approaches more likely to improve stream condition? Does natural plant succession occur on a revegetated slope over time? To successfully answer these questions, the monitoring program must be thoroughly designed and documented with respect to the specific objectives of the monitoring effort, the method and frequency by which the data will be collected and analyzed, and how the results will be presented and utilized (Ward 1989).

Monitoring Techniques

The USDA FS has utilized a variety of techniques in it's erosion control program to evaluate the success of rehabilitation. Water quality monitoring, channel cross-sectional profiles, aerial photogrammetry, vegetation survival, and permanent photo points all provide useful information with varying costs and commitments. The FS uses this information to evaluate erosion control project design, allocate future time and money, and determine the overall effectiveness of the erosion control/restoration program. Other agencies and research groups utilize water quality monitoring results in concert with baseline studies and inventory efforts (Todd and Hoffman 1991).

The quality of water yielded at any point within a watershed is widely recognized as an excellent indicator of the influence of activities and disturbances above that point. The objective of most water-

Defining High Priority Projects

- High erosion and nutrient producer
- Disturbed or unstable stream channel
- Disturbed high erosion hazard lands
- Cooperative funding available
- Volunteer or cooperative labor available
- Controversy, visibility, and politics
- Program mix

Figure 5. Criteria used by the LTBMU to prioritize watershed rehabilitation projects.

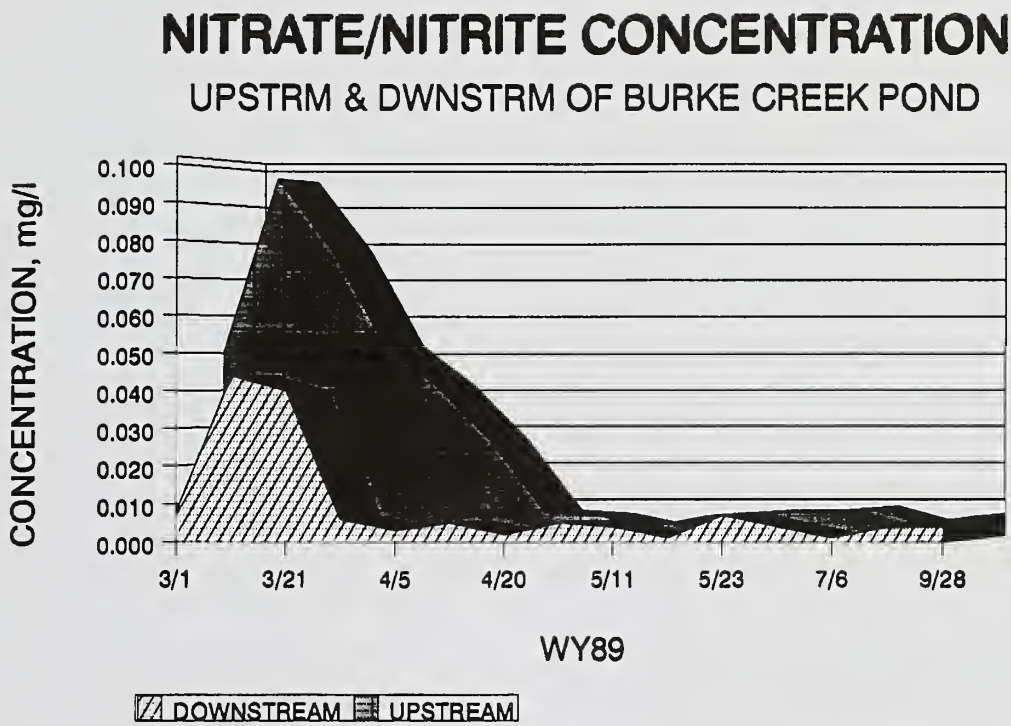

Figure 6. Change in annual water quality values for Burke Creek Erosion Control Project.

shed rehabilitation projects are, in part, the improvement of water quality. As a powerful monitoring tool, water sampling can provide detailed and quantifiable information regarding the effectiveness of erosion control projects (Figure 6). Most sampling is performed to answer cause-and-effect questions. However, only a limited number of watershed rehabilitation projects will lend themselves to meaningful water quality sampling. Due to the intensity and cost of this approach, projects should be chosen carefully.

Sometimes, it is difficult to draw conclusions from what may be observed at specific locations along a stream or a specific erosion control project. Many projects involving rip rap have been successful at stabilizing a point along a stream but have simply transferred stream energy causing erosion problems downstream. Using cross-sectional profiles may be helpful here. Also, comparison of aerial photographs over time have been a popular planning tool for many years. However, new technology has recently provided more options for the use of this technique in erosion control monitoring. The FS was recently faced with a requirement to monitor the effectiveness of numerous biotechnical erosion control revetments along the channel banks of a major tributary to Lake Tahoe. In this case aerial photo-mapping, repeated on 5-10 year intervals was chosen as a monitoring technique.

Photo points are used to document the recovery of erosion control or restoration projects after project completion. The recovery of a project in terms of vegetation growth and apparent site stability is important especially in documenting project success to management, laymen, program supporters, etc. Photo documentation is also essential in providing a historical record of project activities. Monitoring revegetation success through plant survival counts, coverage measurements can be effective in tandem with established photo points.

Long-term monitoring at Lake Tahoe has become an essential part of management. Although baseline information and specific studies are needed to determine progress toward environmental goals, erosion control monitoring is needed to assess the effects of various building plans and mitigation measures currently in progress and under consideration. With enormously costly plans for erosion control work already mandated to meet water quality thresholds in the future, it is important that funds be spent wisely on effective and successful projects and techniques.

CONCLUSIONS

The FS at Lake Tahoe has responded to the need to enhance watershed condition and water quality by developing a comprehensive and integrated approach to a watershed rehabilitation program. The success of this program is due in part to its diversity. By organizing and defining the program, a wide array of potential partners, both internal and external to the watershed program must become involved in accomplishing its objectives. By institutionalizing the need and building watershed rehabilitation into the mainstream of Forest programs, the improvement of areas having poor watershed condition, become a Forest priority. At Lake Tahoe, the combination of these program elements with a passionate and dedicated staff has been an award winning combination.

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Watershed Rehabilitation and Monitoring

William F. Hansen[1]

Abstract.--An overview of watershed rehabilitation is discussed with philosophy, funding, techniques, methodologies and monitoring addressed. Examples of project successes and failures are included. Primary emphasis will be placed on National Forest opportunities and programs to rehabilitate severe natural or man-induced conditions which can dominate water quality and beneficial uses. The information provided may prove helpful to increase management or specialist awareness of rehabilitation opportunities and benefits as well as encourage the use of public participation and involvement to provide support to agency land and resource stewardship efforts.

INTRODUCTION

Sometimes a glance backwards is as important as going forward. I would like to thank all the individuals who have taken part in the group effort to improve watershed conditions on the National Forests. These efforts are often not well known or publicized, but they are a real indication of the grass roots environmental ethic that many within the USDA-Forest Service (USFS) can be proud of. Rehabilitation could not and would not be successful without the proper involvement and support from the many levels of line, staff, specialists and technical personnel throughout the organization. Although not all past efforts have been successful, the vision of improving the quality of the environment and reversing the trend in damaged or declining watershed systems is still alive. Unfortunately many of the early champions of the cause did not leave any written record, so much of the information has had to come from evaluating and interpreting past efforts. Workshops as this are vital to information sharing that must take place to carry "Watershed into the Nineties" as many mid to late career hydrologists seek to keep up with the times and prepare to pass on experience to the new kids on the block.

I apologize that this is not all inclusive as I had neither the time or energy to research and include all the diligent rehabilitation or monitoring efforts on over 150 National Forests. The information presented is in no way intended to be agency policy, but I hope to present a perspective or philosophy that needs repeating - over and over. Rehabilitation of watersheds and ecosystems is a vital part of the Forest Service history and future.

The hydrologist of the "Nineties" is a critical element in National Forest management scheme. The opportunities are ripe to increase public awareness of practices and programs to improve water quality and riparian management. Increased public involvement in rehabilitation projects could go a long way in reestablishing our environmental ethic to our publics.

Few people question a doctors ethics. He makes an investment in his career and patients through hard work and sometimes long hours. So let's consider the hydrologist doctor and the watershed patient. Hydrologists have to make a similar investment if they are going to be taken seriously. So the doctor needs to give a checkup, he asks questions and thumps and prods and runs tests to learn about his patient. Water doctors can't talk to their gigantic patients so they use a combination of methods as aerial photos, pictures, field visits, stream observations and water tests to learn about the patient. Water doctors are still learning to diagnose their patient's condition and provide convincing arguments that

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action is necessary to restore health. In the past, the ability to analyze watershed conditions has generally been confined to the obvious observations with limited ability to analyze the complexities of watershed dynamics. In the immediate future, watershed checkups will be using today's technology including satellite imagery, Geographic Information Systems (GIS), Global Positioning Systems (GPS) and new modeling techniques (grid, dynamic segmentation (GIS), etc.). These tools are really necessary to help the water doctor collect, store and analyze the detailed spacial, time and resource information associated with watersheds. Although these sophisticated systems are the future that many of us are beginning to utilize today, watershed work into the 1990s should allow greater tools for the practitioner-hydrologist to not only look at individual watershed conditions, but also to allow comparison within the population of watersheds under similar or different stresses.

Watershed rehabilitation as a major opportunity for the USFS to standout as experienced leaders in improving damaged or declining riparian ecosystems. Numerous legal and funding options are important to understanding the complexities of National Forest rehabilitation programs. Reference information to consult includes USFS 6509.11K Service-Wide Appropriation Use Handbook and the appropriate personnel in the local Budget and Finance office.

FUNDING OPTIONS

Watershed Resource Improvement (S&W Program)

Watershed improvements with appropriated funds for watershed problems that have no other logical funding avenue or functional responsibility. Some guidance can be found in 2522 of the USFS Manual and 2509.15 Watershed Improvement Handbook.

Watershed Resource Improvement (Knutson-Vandenberg (KV))

Watershed Resource Improvements designated as improvements in Timber Sales with guidance in USFS Handbook 2409.19. Improvements should be identified in prescription and environmental analysis and must be within the sale area boundary. Work must be identified on sale area improvement plan and can be accomplished if sufficient funds are available after regeneration and related activities are complete. If the project is only partially funded, properly applied appropriated or other funds may be used on the unfunded portion. Reductions in sediment and/or improved habitat conditions should be included as part of the project effects analysis whether considered as a connected activity under the National Environmental Policy Act (NEPA) or as a future cumulative effect to take place following the timber sale. Timber sales that also improve severe erosion problems may have a substantial net benefit for water quality.

Agreements

Agreements with groups, agencies or individuals are needed to work together on joint rehabilitation projects. Prime candidates include environmental agencies or groups, resource groups (e.g. Trout Unlimited), mining interests, gas and oil companies, counties, municipal water facilities, etc. There are numerous types of agreements including cooperative, challenge-cost share and interagency. This opportunity is perhaps the most undeveloped and underutilized. For the 1990s, programs such as New Perspectives which favor partnerships and finding new ways to tackle old problems could offer hope and support for rehabilitation needs. References include the 1582 portion of the USFS Manual and the Grants and Agreements Handbook 1509.11. Agreements are the key to treating nonjurisdictional erosion problems within the National Forests (e.g., non-USFS roads).

Rehabilitation through Functional Funding

Erosion control and other rehabilitation measures conducted as a ongoing part of other functional activities including timber sales (Coop Erosion Control), forest roads (Forest Road Program (FRP) funds), developed or dispersed recreation site damage or trails (recreation), wildlife improvements (wildlife), regeneration activities (timber), etc. Rehabilitation needs can sometimes be avoided by identifying and treating water quality problems during regular maintenance or reconstruction. A critical area in functional funding is road maintenance. Engineering typically is not given enough money to maintain roads to quality standards, so water quality suffers. Many of the roads are not maintained as well due to increased recreation use (especially in urban interface

areas) and reduction in timber and road related moneys. If we are going to continue to provide public access, we have a responsibility to provide necessary erosion control maintenance to protect water quality.

Rehabilitation of Special Uses

Rehabilitate watershed damages associated with Special Use Permits. These needs are typically identified as part of the permit requirements. Consider the collection of bond to cover costs in cases where permittee reliability, performance or potential treatment costs or success are a concern (refer to USFS Handbook 1909.03).

Rehabilitation of Hazardous Waste

Funds are made available when the site has been designated as a national priority to clean up. Presently hazardous waste treatment opportunities are identified through the USDA-HAZMAT Program for use of CERCLA/RCRA funding. Special training and procedures are required for the treatment of hazardous wastes. Engineering typically handles this program.

Rehabilitation of Federal Facilities

Federal facilities or lands that do not comply with nonpoint pollution regulations are identified annually by priority for potential funding. Typical projects include underground gas storage tanks, solid waste sites and major nonpoint pollution problems. These problems should be identified on annual inventory of compliance of federal facilities for nonpoint pollution typically conducted by Engineering. Severe erosion problems should probably be included with the inventory of problem areas, but typically these have been low to medium priority for treatment under this program. Engineering is the functional contact for this program.

Emergency Watershed Protection

Refer to the National Emergency Watershed Protection Handbook (published by the Soil Conservation Service, 1988), 3540 of the USFS Manual and CFR 624, Vol 46, No. 221, pages 56577-56579 for direction. Provides for emergency watershed measures after natural disaster (flood, storm, drought, erosion, earthquakes, fires, etc.). Funding is provided by a formal request from the USFS through the USDA-Natural Resources Conservation Service (NRCS). Large disasters require special funding by Congress while the USFS-NRCS has some funding set aside each year to handle some disaster needs. Exigency conditions constitute an immediate threat to life or property and require immediate attention on reporting and completing work. Non-exigency conditions constitute a threat to life or property that is not immediate, but still considered an emergency. Non-exigency conditions require an environmental analysis and are given more time to implement project.

Burn Area Emergency Rehabilitation

Emergency fire rehabilitation is accomplished when watershed damages occur as a result of fire itself with reference to the USFS Handbook 2509.13. and not as a result of suppression activities. Damages from suppression activities are to be handled using FFF suppression funds. Watershed damages include effects from the loss of nutrients, litter and cover on erosive sites; shade and stability along streams; vegetative water use and stability in landslide hazard areas; and ability of the soil to take up and store water. Work is to provide the necessary protection to avoid loss before natural conditions take over to return the area to forest. When treatment costs are less than $2000 and impacts less than 300 acres, the District or Forest should reprogram existing funding to cover costs (USFS Manual 2523.21a). A Burn Area Reoprt is required to be submitted within three days of fire control.

The following are a few examples of rehabilitation efforts on National Forests or associated lands to suggest the variety of opportunities and the complexity of treating severe erosion and riparian damage. Examples include land rehabilitation on the Sumter National Forest (NF), Emergency Water Protection on the Francis Marion NF, wetland restoration on the Savannah River Site, landslide prevention and recovery on the Siskiyou NF and rehabilitation partnerships on the Chattahoochee NF.

LAND REHABILITATION

Watershed conditions of the Sumter NF in the piedmont and mountains of South Carolina were generally poor when the lands were acquired in the early 1930's under authority granted in the Weeks Act. Normal surface hydrology had been modified by past roading and repeated tillage and farming on

sloping land. Inadequate or unmaintained surface drainage allowed erosion to occur unchecked for decades. The results of erosion became a dominate feature of the landscape. Farms, roads and ditches were abandoned. Gullies replaced croplands. Old roads became embedded into the landscape. Surface drainage and erosion led directly into streams. Downstream channels were buried and lost in the sediments. Flooding increased due to lower infiltration and channel storage. The farmed soils became droughty and nutrient poor, unable to grow crops or produce resources. These were certainly "the lands that no one wanted".

A basic understanding of the gully problem is important to treatment. Gully networks do not develop overnight, but may reach some point where they become self-feeding, out-of-control and a symptom of a watershed in trouble. An example of rapid gully expansion occurs when the saprolite layer (highly weathered, incompetent parent material) is reached in the piedmont. Nickpoints (headcuts or drops in channel elevation) can rapidly enlarge and migrate up the channel. The base level adjustment essentially throws all the existing upstream channels out or equilibrium and response includes increased channelization and storm runoff. Although gully formation and enlargement is largely episodic, long term erosion rates from one severe gully on the Tyger Ranger District were calculated (using estimates of landform changes) at exceeding 1000 tons/acre/year on the National Forest. Yoho (1980) referenced annual rates of 80-400 tons/acre. Piedmont soils have been impacted to various levels due to differences in land use, past erosion and ability to recover naturally or under improved management has impacted.

Impacts in gullied terrain are not always obvious but they include reductions in adjacent site conditions, loss in soil macropore space and hydraulic conductivity (Hoover 1949), depletion of shallow water tables and altering of riparian habitats as the runoff prone, surface network expands and the ecosystem maintaining, subsurface flow contracts. Increased flooding problems continue as downstream channels have been filled in (aggraded).

On larger piedmont streams, diverse riparian conditions exist on the alluvial soils. As better land use practices of today prevail, streams are somewhat cleaner and able to begin the long process of channel adjustment and flushing sediment that has deposited. Even though many of the gully sources are not as active as they once were, streams in the piedmont will remain turbid from the channel adjustments for a long time. As these adjustments continue, some of the riparian habitats may be lost as they loose their hydrology and position to the aquatic system, essentially becoming terraces. Other habitats may be gained as aquatic systems return toward historic conditions.

METHODS OF TREATMENT

A variety of methods have been used since the 1930s in numerous attempts to stabilize or rehabilitate the effects of gully, gall and road erosion. Many of the early efforts were more trial and error, as they repeatedly returned to failed treatments to rebuilt them. This section will present topical treatments that have been used and briefly discuss relative costs and success. Design and installation criteria are not discussed in detail.

Reforestation

Early efforts of the Civilian Conservation Corps in the 1930s reforested significant areas of the Sumter NF, reducing surface runoff and erosion to the extent that many active gully systems eventually healed themselves. This treatment was the most inexpensive and most utilized. The healing process was not immediate by just planting trees, but the treatment was effective over a large portion of the problem area. As trees grew and soil cover improved, surface water movement and channel expansion and gully erosion declined. Less eroded areas with better soils would respond best to this limited treatment. All but the worst areas (e.g., saprolite or extremely erodible mica schist soils) responded to this treatment of improving the overall watershed condition to gradually halt gully erosion.

Gully Plugs

Gully plugs consist of a soil dam(s) constructed at some point below the actively expanding area, taking advantage of location(s) of optimum sediment and/or water storage. Typical installations will include a drop inlet structure to provide storage of sediment or water, prevent dam overflow and lower water to the level of the downstream channel. Gully plugs have often been successful when applied to small gullied watersheds of only a few acres. When used on larger watersheds, success is related to pro-

viding adequate drop inlet sizing with emergency overflow or spillway provisions. Fill materials should have adequate clay component to be compacted sufficiently and free of debris that could cause piping.

Gully plugs are not presently used very often due to the cost of the drop inlet structures and the concern about failure. Where concurrent watershed revegetation efforts are implemented to reduce surface runoff, the threat of failure is reduced. Gully plugs can be very effective at providing long term stability. Some structures over 30 years old on the National Forest are filled with sediment to the top of the drop inlet and are still functioning. Their watersheds have been completely forested and there are almost no signs of surface runoff as channels are now ephemeral and well stabilized. Some efforts with gully plugs failed or diverted water to adjacent areas causing new gully development. Most of the failures did not have drop inlet structures or provisions for overflow.

Debris Dams

Debris dams were used on some of the early efforts to stabilize gullied areas. Structures were often made of small cedar trees piled between posts in the gully. Structures provided some short term stability success by slowing water movement and catching sediment. Debris dams break down after a few years and loose their effectiveness. Streamflow around structures is also a problem in larger streams. Straw bales with rebar support have also been used with similar results. Debris dams are not used much today on severe erosion problems associated with gully treatment. Where they can be used to provide some temporary improvement, costs are usually reasonable.

Logging debris has also been used to fill gullies on occasion and can provide some improvement but results are sporadic. Debris fill can be hazardous to foot traffic and increase erosion if burned. Although not specifically field tested, wood chips or chunk wood may provide an excellent treatment to fill active gully heads as long as the water velocity or amount would not be sufficient to move the material (see gravel treatments below).

Rock Dams

Rock dams help stabilize eroding channels or waterways in small watersheds under 100 acres and provide permanent channel protection, water dispersal and allow for high water overflow. Some have been installed when debris dam failure occurred and channel erosion began to accelerate. The rock dams are typically 1-2 feet above the channel with the lowest part of the dam in the channel and highest on the edges, rock continues below the dam to help dissipate energy (especially in the channel if needed). The rock dams typically provide some grade control, energy dissipation and complement other measures on the watershed which reduce the effects of runoff. Costs, proper sizing of materials and frequency of structures are most common considerations. Where materials are readily available and channel access is not a problem, costs can be reasonable.

Gravel Treatments

Gravel treatments have been a relatively recent addition to gully stabilization measures used on the National Forest. Gravel (surgestone - ungraded gravel about 4 inch minus) placed in gully heads or at nickpoints provides effective soil cover and erosion control while allowing present surface water movement pattern. This treatment becomes an effective base level control as water is lowered through and/or over the gravel layer to the base of the nickpoint. This treatment is most likely to be considered when land reshaping is too costly, equipment access is possible and there are no suitable outlets for water diversion.

Gravel (or when necessary rock) is occasionally used to stabilize or maintain waterways, contour trenches or diversion ditches where excessive erosion occurs prior to vegetative cover. The exposed channel shows the best location to place the gravel layer. Gravel placement provides immediate benefits but costs can be a concern. Equipment and labor are necessary to move and place the gravel on the areas needing treatment. A small scoup on the back of a wheel tractor has proven to be excellent tool to move small amounts of gravel to specific sites (Drew 1988). Gravel treatments require less technical knowledge to achieve quality results. Gravel treatments have also been used on entrenched road sections where water diversions were not possible.

Water Diversion

Water diversions are useful to stabilize gully heads if there is a relatively flat, vegetated place to safely divert, disperse and absorb the water without

accelerating erosion on an adjacent area. Costs are generally very low when compared to other methods. The ability to divert water without other treatments may be limited in severely gullied terrain. Some old water diversions provided stability to one gully system only to begin another one elsewhere.

Water diversions are also used to improve road surface drainage. The type of diversion varies with the specific needs of the road but broad based dips, waterbars, berms, water leadouts (trenches), reverse grades and even tank traps have been used. Some of the old entrenched road treatments have used a variety of methods to get the surface water off the road, avoid erosion and reduce the direct conveyance of materials into streams. Diverting road waters into active or healed gullies often creates impacts and should be avoided when possible. Gravel treatments can be used in the gully head if activated.

Land Reshaping

Since the 1970s, this has been the most common method to rehabilitate severe gully erosion on the Sumter NF Initial costs and maintenance are relatively high. This method has provided the best long term rehabilitation for all resources. Practices associated with land reshaping may include building diversion ditches, waterways, contour trenches, ripping the soil (18-24 inches deep and sometimes in two directions), liming, fertilizing, mulching, seeding, planting trees including several years of maintenance. Primary costs are for equipment use.

Experience has shown that some additional practices prevent or reduce operational costs or enhance benefits:

1. Avoid land reshaping during the summer dry period when soil strength is greater causing increased equipment time to push in gully sides. Equipment use in the summer also commands higher rates because of other construction or farming projects.
2. Treat an actively eroding area before it erodes into the saprolite material if possible to avoid rapid gully expansion. Avoid exposing these soils or using as fill material when possible.
3. When moving large amounts of soil any distance, a pan earthmover is almost twice as effective as a dozer resulting in reduced costs.
4. Contour trenches that do not have constant slopes between 1.5 to 2 percent often have maintenance problems from either too much deposition or too much erosion. A suitable outlet of relatively flat and vegetated terrain is needed to spread and filter the runoff.
5. Deep soil ripping improves infiltration and planting trees in rips may also improve survival.
6. Experienced watershed technicians to help plan and supervise the work reduces individual project planning and design costs and allows needed flexibility to meet site specific needs or adjustments.
7. Using grasses or legumes that provide both quality erosion control and wildlife habitat increases project benefits.
8. Instead of burning excess woody debris, utilize opportunities to trap sediment using brush or woody barriers downstream of treatments or pile debris for use by wildlife species.
9. Construct contour trenches of sufficient size (about 2-3 feet deep) to minimize maintenance and prevent failure due to settling of soil.
10. Tree survival and growth are increased if seedlings are planted during the same year as the grass mixture. Development of dense perennial cover makes reforestation difficult and costly.
11. Sometimes tree survival can be improved by inoculating seedlings with the appropriate mycorrhizal species.
12. Maintain the investment by checking and repairing water conveyances, refertilizing or reseeding if necessary. The most critical period is before the area becomes revegetated.
13. Contracting equipment through rental agreement (hourly rate) rather than by the project has generally reduced costs

for projects and provided higher quality work. Less detailed planning, more flexibility to make changes, more control by experienced Forest personnel and less risk to contractor may be some reasons that favor rental agreements.

Economics

Some people take exception to the costs of aggressively treating severe erosion (ranging from $500-5000 per acre). They are correct, costs are high, often more than the land is worth. It is also costly to pull underground gasoline storage tanks, rehabilitate hazardous waste dumps and pick up trash along the highways. These are all forms of pollution. Most of the time, it costs much more to fix a problem than to prevent it. Had preventative land practices such as Best Management Practices (BMPs) been used, much of the costs of repairing or living with pollution problems would not be incurred. The costs that we bear to live with pollution problems are not always obvious. If the costs of poor land ethics could be listed as decreased productivity, increased need to till, fertilize and use pesticides, higher costs for water treatment, increased flood damage, reduced reservoir capacity, impacted riparian, estuary and wetland habitats and altered stream/groundwater dynamics, they would certainly be intolerable.

Accomplishments

Gully rehabilitation on the Sumter NF started out slowly with only a few acres accomplished each year by the CCC or other special emphasis programs such as PL-566 administered by the Natural Resources Conservation Service. Initial efforts had some successes and many failures requiring rework or design adjustments. Funding and programs were sporadic and little is known about any monitoring efforts to evaluate or maintain past accomplishments. By the latter 1970's, the Forest was annually treating 10-20 acres using U.S. Forest Service watershed improvement funds. As a result of the National Forest Management Act of 1976, watershed and other resource improvements using timber receipts were authorized using Knutson-Vandenberg (KV) funding. Approximately 1,800 acres of severely eroding lands have been treated since 1980 using KV and appropriated funds.

Funds to improve watershed conditions from Sumter NF timber sale receipts have net positive benefits to resources (soil, water, wildlife, visuals, timber). Where possible, these benefits are included with timber sale reporting measures. Success is not only measured in the reduced tons of sediment being delivered to streams or the marked improvement in land productivity, but it is also measured in the renewed interest in land ethics when the projects are shown to others. The opportunity to put something back into the land has long been appreciated by Forest Service employees.

Emergency Watershed Protection

In September 1989, Hurricane Hugo hit coastal South Carolina and left a major portion of the Francis Marion NF with completely twisted and sheared pine trees and intermittently uprooted and windthrown bottomland hardwoods. It was several weeks before the major roads could be traveled to assess damage. Needless to say, we were not able to meet the normal time table to request funds or accomplish work. The Forest Supervisor chose the Forest Hydrologist, Soil Scientist, Fishery Biologist and Preconstruction Engineer to evaluate EWP needs. The team took about one week to sample and inventory problems, identify alternatives, document effects and prepare an Environmental Analysis with appropriate Decision Document. The emergency conditions existed for months due to the widespread damages.

The Decision Notice required much less intense stream cleanout than was being used in more populated areas. The activity selected provided cleanup of channel debris within 200 feet of bridges and culverts as needed. Specifically avoided were activities that would completely clear channels and remove debris through the wetlands. Heavy equipment would operate from the road unless specifically authorized where wetland and cultural resources would be protected. The alternative selected cost less than 10 percent of the full treatment option and kept the stream channels and associated wetlands ecosystem intact with little disturbance from heavy equipment with the understanding that some minor channel adjustments were likely from the added debris in uncleared areas.

Work was conducted with Emergency Equipment Rental Agreements (EERAs) in which verbal bids for equipment with operator were sought from potential contractors. Equipment rented included chainsaws, trackhoe, skidders and dozer with operator and when necessary a helper to efficiently use the equipment. Skidders were equipped with winches containing at least 250 feet of 5/8 inch cable. Workers supplied their own safety equipment and chest waders to work under the variety of riparian and aquatic conditions. Some advantages of the EERAs include speed to begin work, little paperwork other than normal recordkeeping, pay only when equipment is working and increased ability to control the amount and quality of work from the variety of conditions present. Disadvantages are the continuing need to supervise, direct and/or check on work and difficulty in maintaining contact with work crews scattered over 500 miles of forest roads.

The results of the work provided the desired protection of the wetlands, visuals, cultural resources and aquatic habitat with reasonable assurance that water blockage would not become a problem at road crossings. Without a doubt, some channel adjustments continue as debris blocked or diverted some flow patterns. The project costs and the effects on riparian habitat and visual conditions were less than trying to remove all the debris from weakly defined channels in the coastal plain. No significant problems from culvert or bridge blockage have been encountered in the three years following Hurricane Hugo.

Wetland Restoration

Repair of damaged wetland conditions has the potential to become a fast growing topic in the 1990s. Primary emphasis would be given on restoring the hydrologic function and vegetation. It was not much more than a few decades ago, when there was no second thought to draining or filling a wetland, channelizing rivers or flooding riparian areas. In society's aggressiveness to make every acre productive, some of the best riparian habitats were damaged or destroyed. Times have changed and hydrologists should have a lead role in identifying and recommending recovery measures to rehabilitate wetlands. Repairing hydrologic modifications is often the key element to reversing past changes and returning ecosystem function.

In 1989, an interdisciplinary team of hydrology, soils, plant ecology and landscape architecture skills developed an Environmental Analysis and Recovery Plan at the Savannah River Plant Site (SRP) for the recovery of a Carolina Bay (Hansen et. al. 1989). The M-Basin/Lost Lake recovery team was formed following contaminated soil removal efforts were completed after a hazardous spill. The team identified opportunities to fill the drainage ditch which allowed farming of Lost Lake prior to the 1950s and plant vegetation to improve the visual conditions, wetland habitat and erosion control. Three treatment alternatives were developed for wetland restoration including: 1) return to natural hydrology and establishment of only native plants, 2) rapid recovery of visual conditions with introduced wetland species and 3) allowing natural succession to occur. All treatments included erosion control measures to stabilize barren soils impacted by removal of contaminated soils. The actual recovery effort built on this initial analysis with modifications after intense multiple agency review on the SRP.

Landslide Prevention and Recovery

Past work and observations on the Siskiyou NF in southwestern Oregon and familiarity with some similar problems in mountainous terrain elsewhere justify mention of this critical topic. Most of the landslides in coastal Oregon were in unstable land terrain. The high rainfall (up to 150 inches), water yield (up to 125 inches), geologically recent faulting and uplift of the coastal range with associated steep slopes and channel gradients and the possibility of severe storms including rain on snow events combined to make this area sensitive to slope failure. Certain soil types were more prone to specific types of failures (e.g., soil creep, land slump, landslide, debris avalanche). Land failure increased when natural conditions or management practices exceed hydrological or soil thresholds demanding adjustment. Some critical topics that need special consideration during management operations appeared over and over as follows:

1. Road surface drainage was funneling excessive water directly onto steep slopes or drainages unable to cope with the increased flow. Spacing between cross drains is a critical factor.

2. Wet weather use of outsloped, unsurfaced roads without dips or reverse grades resulted in runoff being confined into wheeltracks, concentrating flow over fill slopes causing severe fill erosion.
3. Slope failure often occurred in steep gradient headwater channels where road construction cut into the supporting slope. Failure can be a result of a combination of many factors including the loss in soil support due to soil removal or root strength, the change in surface and subsurface flow dynamics in the road prism area and the increase in soil moisture due to timber harvest.
4. Old road systems had a greater frequency of failure because they had: a) often overdesigned in width, b) sidecast fill in steep areas, c) too much space between cross drains, and d) did not avoid or provide special design in landslide prone soils (i.e., those that become plastic or liquid upon saturation such as soils with mica, talc or gypsum or other slippery materials) or shallow to moderate depth soils underlain by rock dipping parallel to the slope.
5. Naturally occurring severe events (e.g., rainfall, floods, wind, wildfire, geologic uplift, volcanic intrusion) and unusual combinations or natural or man caused conditions contribute to and compound landslide dynamics.

Careful evaluation and consideration of all factors was best conducted as a team with hydrology, soils, geology, fisheries and engineering expertise. Burial of stream channels below landslides can create untold analysis problems as the team will have to evaluate potential problems to the stream channel, downstream hazards and resource impacts. Measurements and observations were important in determining the causes and actions to take. Training and field assistance trips were used to increase personnel awareness of the signs that suggest potential problems (e.g. jackstrawed trees, hummocky terrain, soil cracks, cracks in fill, pistol butted trees or shrubs, rock outcrops with moisture in high gradient headwater channels, entrenched channels). Although roads were the primary activity identified or associated with land failure, many failures could have been prevented with proper hazard inventory, road location, design or early treatment when warning signs are detected. Seismic analysis, aerial photo analysis and other field interpretations provided by geologists and soil scientists were vital to hazard identification and avoidance when possible.

A variety of methods, techniques and materials were used in attempts to prevent, stabilize or minimize the effects of landslides. Compared to the amount of soil released in a large landslide, only a small portion typically remains to stabilize. Cordones, woody cuttings buried on steep slope contours, provide continuous vegetated check dams across unstable soil slopes and were the best vegetative treatment for adding stability on steep slopes (Sims 1980). Early treatment of cracks in road fill prevented some failures that would have occurred. Horizontal drains were sometimes installed in landflow or saturated fill conditions to capture and drain the underground waters to the surface. In several instances, sufficient water was removed to prevent further problems mass movement or slow soil creep.

A geologist showed me how to use two welding rods to locate underground water prior to installing the horizontal drains (Cornell 1980). The rods are bent at 90 degree angles about 6-8 inches from the uncoated end. They are used by holding one in each hand and with the long section pointing toward the direction of travel as one walks across the suspected underground channel or water conveyance. Upon crossing the underground water, the rods rotate from the forward direction parallel to each other to linear coincidence either touching each other or thrown away from each other as if magnetically affected by some geophysical force field.

Fencing materials and measures were tried including rock filled gabions. Some of the most effective structures were simple fences installed across headwater failure areas using chain link fence and steel fence posts, with or without filter cloth to hold back rock and sediments. Location of fence structures were selected to instill stability or increase ability to store more sediment deposits. Careful attention to keep the lowest part of the fence in the channel and holding the bottom of the fence to the soil with rebar were important considerations. Chain link fence is especially strong and flexible, though quite heavy to be moving very far when access is a

problem. It rolls and tumbles well down barren landslides, but a rope may be needed to prevent runaway or tangling in vegetation.

Diverting any road surface drainage was one of the first steps to reducing impacts following failure. But when landslides were down to bedrock, there was little need in diverting the water, especially when adjacent areas are equally unstable. Fertilizing, seeding and mulching helped reduce surface erosion from some of the bare slopes but probably did little to stabilize the areas. Hydromulching also worked well at providing ground cover vegetation on steep slopes and politically was supported from the improved visual condition. Hydromulching was conducted up to about 1000 feet from the batch truck as long as the elevation drop is not so great as to cause problems in holding the hose under high pressure.

Channel treatments were occasionally tried when debris avalanches or mass failure buried stream channels. Many factors had to be weighed including the ability of the stream to assimilate or adjust to rapid change without triggering other mass failure in adjacent slopes. Channel and slope dynamics in undamaged stream sections provided helpful ideas on how to treat damaged conditions. Huge mass failures, large woody debris blockage, sluiced channels and inaccessibility combined to make treatment of many areas impractical. Sometimes it is more prudent to let the natural processes work.

Rehabilitation Partnerships

The Tallulah Ranger District on the Chattahoochee NF in Northeast Georgia has to be one of the best Districts for cooperative efforts. Their coordination with Trout Unlimited, County, State and other groups to address soil and water issues has been an inspiration and justify their receipt of several partnership and conservation awards. They are eager to discuss soil and water problems and take seriously their treatment. Agreements or partnerships are used to augment funding, personnel and equipment needs. These partnerships often highlight soil and water problems on private lands that are affecting National Forest resources. Increased awareness and interest suggest non-USFS partnerships may develop to treat some of these nonjurisdictional water quality problems. Working with our neighbors and interest groups in a nonconfrontational manner, the District continues to provide information and facilitate discussion on mutual interests.

One example of this cooperative effort occurred in the Reed Creek watershed and fishery improvement project in response to public concern over loss in trout habitat from erosion and sedimentation (Hansen et.al. 1991). In a truly amazing effort, the District orchestrated over a several year period, numerous small projects that combined to improve water quality, reduce active sediment sources and increase stream fishery habitat. The District not only utilized appropriated watershed, recreation, fishery and engineering funding, but also donated funds and services from numerous agencies and groups. Treatment of sediment from contributing roads, trails and dispersed sites and fishery improvement with 60 fish structures has improved the trout population. Contributing agencies and groups included Trout Unlimited, Rabun County, Georgia Power, Georgia Department of Natural Resources, Student Conservation Association, Youth Conservation Corps, Vulcan Materials, Chevron Corporation, FishAmerica Foundation, Coweeta Hydrologic Laboratory and some local individuals.

Monitoring

Research experience and responsibility while at the University of Missouri provided some excellent technical skills, but did not necessarily provide the insight to foresee some of the problems in National Forest monitoring. While on the Siskiyou NF, with the support of John Millet, Watershed Staff Officer, assistance from Malcolm Drake, Hydrologic Technician, and other hydrologists as they came on board, we had one of the largest monitoring programs in Region 6 with approximately 30 automated water samplers, 40 recording thermographs, 5 recording raingages, 10 recording stream gaging stations in cooperation with the State Watermaster and probably over 100 sites where occasional peak or low flow measures were taken. We had at least 5 fluorometers on the Forest used in monitoring aerial herbicide application projects. We carried heavy equipment into remote areas and sometimes worked during hazardous conditions or on donated time to collect information. Some of the data was summarized or prepared into short reports. Unfortunately person-

nel diversion to other projects and the transferring of hydrologists before work could be completed, left some projects unfinished. Reflecting on the past, there are several weak links in this process that dilute monitoring effectiveness.

Some typical weak links in water monitoring included: 1) monitoring more than funded or staffed for, 2) transferring of hydrologists, 3) little encouragement to report or publish findings, 4) lack of priority compared to other duties, 5) irregular support in the budgetary process, 6) changing emphasis under different management regime, 7) collecting more information than is needed for the issues or concerns, and 8) insufficient ties to other programs such as fisheries, research, State Forestry and Water Quality and US Geological Survey where mutual benefits in data collection and/or reporting could be achieved.

Some of these barriers could obviously be overcome by: 1) specifically funding projects as line items; 2) encouraging greater interaction or possible short term details between transferring and replacement hydrologists; 3) increasing priority on reporting and/or publishing findings; 4) conducting work load, staffing and contracting needs analyses; 5) hiring hydrologic technicians where appropriate to add continuity; 6) designing projects to address only the specific issues of concern; and 7) seeking partnerships or agreements with those conducting similar work, with supportive facilities and/or funding.

Perhaps disillusioned by some early failures, the following have proven to be some practical ideas or measures with the limited funding and commitment available that can help answer specific issues typical to most Forests:

1. Erosion or sedimentation - Install fence with filter fabric at the base of specific culverts, road or trail sections, slopes representing or in ephemeral or small intermittent drainages to capture sediments of land treatments of concern. Use surveyed cross sections to estimate the volume of material deposited between visits. This idea was adapted from some past work using this basic technique (Dissmeyer 1982). It is inexpensive, fast, reliable and does not require specific service intervals. Sometimes filter fences installed during normal road construction can be used with some additional work.
2. Low elevation aerial photos are especially effective at monitoring implementation of practices as seeding, water bars, stream buffers and locating any gross erosion problems or maintenance needs associated with activities. This has been an excellent tool to keep District Rangers and Staff informed on a variety of conditions associated with activities. Using GPS, pilots can either pinpoint the exact locations of pictures taken or fly to a specific location and take necessary photo(s).
3. Photos points or video recordings can be an effective tool to document specific monitoring methods or conditions. These are often needed in reporting or marketing monitoring results.
4. Document stream observations or field indicators when monitoring specific activities. For example, identify fresh sediments following activities in stream channels. Walk the stream until the source(s) can be identified and pinpoint the specific problem. This approach is not quantitative, but can be easily used to help address effectiveness issues. Sample above and below an activity after several flushing storms and find no signs of fresh sediment in the pools or margins of the stream, therefore you have a good reason to believe the erosion control measures used were effective. Note: some of the recent work on pebble counts by Dave Rosgen shows promise to quantitatively address this issue.
5. Hydrological monitoring is best developed around specific issues or conditions when the undesired impacts are most likely to occur. The scheduling may not always fit into the normal office work hours and may require immediate or preferential attention to sample. By sampling under the "worse or bad conditions", one can document and possibly discard or weaken the importance of some of the issues or concerns. Some examples would be to sample erosion and sediment when it is occurring (i.e., during significant runoff events). Sample pesticide applications during and immediately following appli-

cation or during runoff events after time of travel measurements or estimates are made. Monitor gully rehabilitation after one or more major events at waterway or contour trench outlets (the prime areas of failure). Monitor the changes in stream temperature during the season when the combination of solar intensity and duration and reduction in streamflow typically produce the maximum change (typically July through September in mid to late afternoon). Monitor the effects of a stream crossing during culvert installation and first storm event(s) following installation. Making the sampling simple and directed to specific measurements will often be the best approach when limited time and money can be spent. Failure to do this can greatly increase the monitoring cost and reduce effectiveness (e.g., monitoring sediment effects from a timber harvest on a regular monthly schedule for events that occur less than 5 percent of the time yields a probability of sampling success during 12 months equal to .05 X 12 = 0.6). Instead of going out during the storm and getting it over with, 12 trips would be made to the site, many or even all of them wasted because it was not raining and erosion/sediment processes were not very active. Sure there is plenty of data for statistics, but unfortunately the issue for which an answer was sought may not have been sampled and the data collected could be misleading.

6. Use monitoring surrogates (e.g., aquatic insects or fish) as indicators where activity is likely to produce some noticeable or substantial change in habitat or biological requirements if not properly implemented. Work conducted on the 1983 Western Spruce Budworm project in Oregon showed that aquatic insect drift or benthic samples are excellent to use when applying insecticides or to follow up spill reports or landowner complaints (Hansen and Silovsky 1984). Diversity indices and substantial shifts in population or species can be helpful in assessing impacts.
7. Know what has been done on the issue or concern. Perhaps suitable research or studies have been conducted that could directly or indirectly apply to the situation. Without a better system to provide technology transfer between and among other hydrologists, much of the information that may be collected on a specific issue is in file cabinets or some little known report. Raw data as in STORET may be useful, but without specific interpretation and analysis from the responsible party, the information is more difficult to use to answer specific issues or concerns.
8. When monitoring rehabilitation work, the first few major storm and any flood events are most critical to check water control structures. When successful revegetation is important to recovery, periodic checks for germination, growth and need of refertilization are useful. Monitoring recovery of rehabilitated areas and timely maintenance as necessary are important aspects to ensure protection of investment.

CONCLUSIONS

Early conservationists recognized the need to utilize resources wisely. Congress has been convinced and acted on the importance of land stewardship in significant legislation. The National Forests have a long history of preserving, maintaining, improving or restoring watershed conditions. Agency activities have not always put stewardship first, but the USFS has always been ahead of the times at taking a prudent strategy to achieve long term balance, productivity and maintenance of a variety of resources. Since the passage of the Clean Water Act, preventative practices are upgraded as necessary to agree with BMPs recommended by States to minimize impacts to water quality and associated uses on all forest lands. Implementation of BMPs is a giant step to improve water quality in the future. But water quality is also controlled by the past. Rehabilitation opportunities can help reverse the declining trend in some watersheds and shorten recovery times.

Water quality can be immediately improved with the aggressive treatment of active erosion problems which reach streamcourses. By taking advantage of

the options available to fund and treat declining watershed problems, hydrologists can make a real difference.

Some of the opportunities for watershed rehabilitation may be lost or reduced due to the reduction in dollars associated with timber sales as the USFS moves away from the traditional clearcutting to less efficient methods. Funding will be sought elsewhere and ways to cut costs explored. Funding from other functional areas and agreements/partnerships with others will probably increase substantially as concern over aquatic and riparian habitats and water quality continues. Marketing the rehabilitation opportunities will become more critical as a greater level of management and public support will be needed for program growth. Increasing interaction with State, Federal and local NPS programs, developing partnerships and technology transfer are key elements to broaden the support needed.

When faced with severe erosion on private lands affecting National Forest resources, treatment or non-treatment is at the discretion on the landowner. Treatment is costly and has not gained much popularity when landowners have to foot the bill alone. Many of the benefits will not accrue to the landowner. Non-treatment is also costly, but the costs are not always obvious and many are born by the public at large. However substantial opportunity exists for the landowner to secure cost-sharing or other support through cooperative agreement or partnerships. Perhaps there is an increasing role for the hydrologist to increase public awareness and help facilitate information transfer that a problem exists and there may be opportunities for treatment.

The results presented cannot be attributed to any one individual effort. Land rehabilitation has been achieved through time from early conservationists, appropriate legislation, identifying and using opportunities. Numerous individual efforts of USFS personnel and often others were necessary to achieve the results presented in these examples.

Monitoring is another subject under careful evaluation across the National Forests. Although the methods and intensity of monitoring can vary significantly, depending on the project objectives and sensitivity, the USFS can encourage and support monitoring programs by providing for funding in Forest Plans and project activities. Monitoring targets could be associated with the project plans when they are properly funded. Increased collaborative efforts among hydrologists and similar monitoring efforts could enhance results. The USFS has some of the finest hydrological talent, skills and experience in the nation as was evident in the Workshop. Our collective effectiveness in water resource management and forest hydrology will increase as our ability to transfer technology, coordinate similar work, network and share results.

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Watershed Restoration on the French Mesa Grazing Allotment

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Abstract.--A Watershed Condition Inventory was completed on the French Mesa Grazing Allotment on the Santa Fe National Forest in north central New Mexico in 1988. This inventory identified and documented numerous erosional problems which were linked to ongoing land management practices. Meetings were held with allotment permittees and an interdisciplinary Forest Service planning team. The team was successful in reaching consensus with the permittees and restoration measures were employed. These measures included earth dam gully plugs, sage brush mowing, fencing which created new pastures, road management, and repair of existing developments. The key to success was in establishing cooperative ties with the permittees and overcoming historic attitudes.

INTRODUCTION

Overgrazing on public lands has long been identified as a land management activity which has impacted water quality in the West, sometimes with devastating effects. If managed properly, grazing can exist with little effect on water quality. Proper grazing management requires more time, effort, and monitoring than past practices. However, the results can be quite dramatic.

On the Coyote Ranger District of the Santa Fe National Forest (NF) in north-central New Mexico, a struggle to improve grazing practices is taking place on the French Mesa grazing allotment. The area is located five miles northeast of the community of Gallina. The major drainage in the area is the Cañada de la Cueva, which flows directly into the Rio Gallina.

Tremendous amounts of sediment have been delivered to the Rio Gallina from French Mesa; much of the sediment problem is directly tied to past grazing management. Increased sedimentation in a stream decreases available macroinvertebrate habitat, covers trout spawning gravel, and is associated with other adverse water quality indicators.

HISTORY

The French Mesa area is likely to have been grazed for almost 150 years. The first settlement in the area was along the Rio Cañones, founded in the mid-1700's[3]. Gallina and Coyote were later settlements. The traditional grazing method used higher elevations during the summer months. In mid-May the cattle were driven from the lowlands to the summer pastures where they were left until late October. Numbers were unregulated, as were the locations where the livestock concentrated. It was unlikely that grazing pressures were high during the Spanish period as grazing was generally for sustenance and not commercial. Available winter forage may have been a severe limiting factor[4].

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[3] *Briggs, Charles L., and John R. Van Ness, Land, Water, and Culture: New Perspectives on Hispanic Land Grants.*

[4] *Westphall, Victor. 1983. Mercedes Reales: Hispanic Land Grants of the Upper Rio Grande Region, University of New Mexico Press, Albuquerque.*

Following the Organic Act in 1898 and the 1905 creation of the U.S. Forest Service (FS), grazing use continued more or less in the same areas and seasons, thus creating the allotment boundaries which in many cases exist today. The FS management decreased numbers of sheep and goats, and encouraged cattle. This change from mostly sheep and goats to cattle may have increased grazing pressure on grass and forb species favored by cattle.

The Coyote District built fences breaking each allotment into four pastures between 1963 to 1966[5]. The cattle were to be placed in one pasture for a short time, then rotated to the next. This system, called rest-rotation grazing, allows for grazing on one pasture for a short time only once each year. This gives the plants the rest of the growing season to recover. No pasture is grazed at the same time in any consecutive year, which eliminates the possibility of one given portion of the growth cycle being impacted repeatedly.

Despite efforts by the FS, the new system of grazing management did not work, due to lack of cooperation from the permittees. "They were not very interested in keeping the pasture gates closed."[6]

The political situation in Coyote has been difficult for the FS. Northern New Mexicans have traditionally resisted direction from federal agencies, preferring to be self-sufficient. It is this resistance which has made it difficult to make any changes in grazing management. One of the problems is that the FS tried to dictate its management plans, instead of initiating dialogue. In order for a system to work, there must be some education from both parties." The permittees often had valid ideas, and the land managers need to be able to recognize this and incorporate their suggestions into the management plans.

The political situation in Northern New Mexico came to a head in June, 1967, when Reyes Tijerina took control of the Rio Arriba County Courthouse in Tierra Amarilla, claiming ownership of much land under Federal ownership. The French Mesa area was a part of the disputed area. The FS backed off from northern New Mexico, and attempts to convince the grazing permittees to adopt new grazing management strategies for the most part ceased.

[5] *Personal communication, Pete Tatschl, 1992.*

[6] *Personal Communication, Pete Tatschl, 1992.*

THE PROBLEM

During early 1988, personnel on the Coyote District began analyzing grazing management on French Mesa as required by the Santa Fe NF Plan. One of the problems with the allotment was related to the type and amount of vegetation, directly caused by past grazing.

Cattle are by nature lazy animals. When unmanaged, they tend to "lounge" around water sources, moving only as far as needed to graze. The vegetation in those areas gets severely overgrazed, and will change in species composition. Over time, the vegetation changed from late-ceral, or an ecologically mature community consisting of bunch grasses, to a less mature community, which is dominated by sod-bound grass and sage brush. This happens when an area is continually grazed. Sod-bound grasses have more biomass below ground (as opposed to bunch grasses), and are, therefore, not as susceptible to grazing pressure. This was the situation found on French Mesa during a review in 1989.

This species change was not beneficial to watershed condition, either. Erosion rates were far beyond geologic rates. Evidence of sheet flow and active gully (arroyo) cutting were prevalent.

A Watershed Inventory/Needs Survey (WINS) was completed in October 1988. The WINS found that this decreased ground cover resulted in increased storm runoff. Flows became greater, forming rills and then gully systems (Figure 1). These features often developed along livestock trails which run up and down valley bottoms. It was felt that the gully system would continue to erode upchannel until either a geologic barrier or an equilibrium is reached. The potential for additional damage was quite great.

Another problem associated with the downcutting of arroyos is that shallow groundwater is drained, furthering the vegetative decline. Some of the gullies were over 15 feet deep.

RESTORATION

Different approaches were needed to address the problems found on French Mesa. First, problems associated with the gully network needed to be addressed if there was to be any land remaining for grazing. Second, there needed to be a change in the plant community. These factors ultimately came down to one factor--without proper grazing management, there could be no solution.

Figure 1. Representative arroyo on French Mesa.

In 1989 a rough draft of the Allotment Management Plan and the WINS inventory was completed. The draft allotment plan adopted a five pasture rest-rotation plan, and the WINS identified problem areas and proposed solutions. The next big step was to convince the permittees of the merit of the plan.

In the summer of 1989, five earth dam gully structures were constructed, and proved to have several benefits. These structures served several purposes--water sources for cattle, which disperse them over a broader area of the range, sediment traps, and raising the water table. Later, another use was found by waterfowl that raised a brood of ducklings on one of them.

Grazing continued as usual during 1989. It was felt that once the permittees saw that water was being established in areas that had none in recent memory, they would be more receptive to other changes, like adopting rest-rotation grazing practices. Talks with the permittees were complicated by the fact that other permittees on the District ridiculed the French Mesa group for even talking to the Forest.

During the summer of 1990, which was very dry, the French Mesa permittees were the only permittees on the District not to be affected by lack of dependable water. The new structures helped to give the FS some measure of respect. The water sources did not go unnoticed by the other permittees.

The FS then paid for three miles of electric fence, which the permittees themselves installed. This was the first time that the permittees and the Coyote District cooperated on such a project. Also, several additional earth dam structures were built. The rest-rotation method was also implemented that year, to some result. The summer of 1990 was a tough year. The permittees were learning the new system, and the FS was learning to listen to them. For example, when a pasture has been grazed and it is time to move to the next, the most healthy pasture is the one selected. The permittees wanted to be the ones to select the pasture. District personnel consented, and so far there have been no disagreements. The permittees have a good inherent knowledge of what is healthy.

PRELIMINARY RESULTS

The results to this point are quite dramatic. The permittees have already noticed an increase in weight of the cattle going to market. In addition, the calves being born are both heavier and healthier.

The watershed condition is also improving (Figure 2). A field inspection in late summer of 1991 showed cattails growing at the water's edge on several structures. Sagebrush in the area is dying off, up to 300 feet from the water's edge, which indicates the water table is raising. In addition, water seeping

Figure 2. Inundated arroyo following construction of earth dam.

around or under the structures has created a perennial trickle below the structures. Although this project was implemented quite recently, the results are promising.

The most difficult part of the project was establishing communication between the permittees and the FS. It was essential that a measure of trust be gained by both parties. Now permittees on other grazing allotments are very interested in doing similar projects. The District has two Allotment Management Plans due to be implemented this year, and two more in the works.

Water quality benefitted immediately. Sediment yield from the watershed has been reduced to near geologic levels by the structures. Over the long term these structures will silt in, filling the arroyos with alluvium. It is hoped at this point that natural pre-livestock induced valley aggradation or valley floor build-up will occur as sediment is deposited by broad, shallow flood waters. Eventually, over the next thousand years or so all traces of the man-made earth dams may be buried by natural sediment deposition occurring in a relatively lush looking, broad valley bottom.

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Information Management: A Framework for the Future

Teresa A. Spencer[1]

Abstract.--The Forest Service is under increasing pressure to manage its information more effectively. The Agency has recently adopted an Information Management Framework to guide it in doing so. If the effort is to be successful, every employee needs to be part of the team.

WHY MANAGE INFORMATION?

Managing information isn't about the DG, GIS, or microcomputers. Those are just tools. It means getting the right data to the right people at the right time in the right format.

It isn't just a technical matter, which technical people (such as the computer section) can solve. They're part of the team, but every employee needs to be part of the team, too. Every employee manages information of some kind, so every employee has a stake in how the Agency wants it done. If the Agency continues to treat information management as a purely technical matter, it will continue to get the kinds of solutions to information management problems that it has always gotten, the kind that technical people have been trained to provide.

Indications are that these kinds of solutions are no longer sufficient. Congress is tired of getting inconsistent answers. The public wants kinds of information the Agency is not set up to provide. Both want faster response times. Managers and technical specialists within the Agency want to be able to do more complex analyses and models, which can't be supported very well in the current information environment.

In response to the internal and external pressures, the Forest Service has begun to move toward a desired future condition in which the Agency:

- Recognizes information as a resource critical to our success.
- Shares and manages information in ways that support the mission and business of the organization.
- Strives, as a commonly understood, accepted, and supported goal, to bring quality information, in the right form, to the right people, at the right time to support sound and deliberate decisions and to generate ideas.

One part of the problem is that in the past, most computer programs functioned independently of each other, relying on their own separate sets of data. The same piece of data often osccurred in multiple sets of data, often even being collected and formatted separately for each. This has improved slightly over the years, so that today clusters of programs may work together off a single set of data; however, there is still little coordination between clusters. The Agency's desired future condition points toward a situation where data is collected and stored in a common fashion and accessed through a common interface, using common programs where possible.

Stated another way, the Forest Service is moving toward integrating data (improving communication and sharing) and coordinating applications (improving efficiency) in order to provide quality management information (improving effectiveness). Does this mean that all data would be stored in a single huge database? Probably not. It is a concept of multiple databases designed as a set of interlocking jigsaw puzzle pieces and sharing these characteristics:

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- Each piece of data occurring in only place.
- Each database shareable by all appropriate applications and users.
- Updates automatically synchronized.
- Data flowing easily in and out.
- Data security and integrity controlled appropriately.
- Allowing synchronous real-time business to be conducted.

HOW TO MANAGE INFORMATION

In 1992, Chief and Staff approved a series of recommendations pulled together into a package called the Forest Service Information Management Framework. It consists of the vision stated above, an information ethic, a set of information management principles, and seven strategies for moving the Agency toward the vision. Chief and Staff recognized that this is not a process which will occur overnight, but rather one which will required a migration from the current environment to the desired future environment.

For one thing, realizing the vision will depend on each of us recognizing and seeking to practice an ethic in which:

- We subscribe to the notion that people who develop and manage information are stewards of the information, not owners.
- We recognize we are stakeholders in the information management vision and principles, and strive to help the organization achieve them.
- We subscribe to the value and need for corporate standards, but also strive for flexibility so that our individual creativity in getting our personal job done is enhanced.
- We recognize the need to synergize our local and functional information agendas with the corporate information agenda.
- We value having a consistent technology platform that is available to all employees in all offices, and strive to use the corporate technology platform whenever practical so that we do not isolate our information from others who could beneficially use it.

Embodied in the vision and the concept of information management are a number of basic principles:

- Information management is an integral part of every Forest Service program.
- Information systems are designed to help meet business needs.
- Data are captured at their source as a natural course of conducting Forest Service business.
- Data are entered once and used often.
- A shared data environment consists of integrateable databases coordinated through modern data management technology.
- Widely used, commonly understood, and persistent data, information, and processes are standardized.
- Data are consistent to the extent that implementation at each level, and across units, is compatible and mutually supportive.
- A shared-data environment ensures that information is available to employees and processes as needed.
- Data and information are shared with external cooperators and the public.
- A technology infrastructure exists to support the business of the Forest Service at all locations.

Additional details are available in the January 1992 Forest Service report, Information Management: A Framework for the Future.

WHAT DOES THIS MEAN FOR A HYDROLOGIST?

Attaining the vision means some amount of technical change (such as implementing Project 615 or choosing a standard information engineering methodology). But the larger change will be cultural change within the Agency. For instance, unit managers will need to take a greater interest in how in formation is handled within the unit. Technical specialists, such as Ranger Conservationists or Hydrologists, will need to be more directly involved in designing and managing their databases and the systems which access them. Some of the areas which will be changing which will require a strong partnership between the technical and the nontechnical folks are:

- Coordinated inventories
- Shared databases
- Coordinated software

- Standards (data, coding and terminology, software)
- Planning for system development.

So what can a hydrologist do now to become involved in shaping the future?

- Become aware. Learn whatever you can about where the Agency is heading in managing information. Every employee deals with information; the more you are aware of how to manage it, the more effective a tool it will be for you.
- Help develop standards. A common language will be critical to achieving the desired future environment.
- Get involved in the planning that will occur over the next few years. It's your chance to be heard.
- Develop partnerships. Whether you just informally agree to work more closely with the specialist at the next desk, or you make a more formal agreement to work together with another discipline to develop a joint database, begin the process. Ultimately, it doesn't matter whether two computer programs work together; the more important achievement is that the people who use them recognize the value of working together and do something to make it happen.
- Stay involved. You are the only one who knows how you think the world should work. Seize your chance to help shape the future of information management.

One thing you can be sure of is that things will continue to change. In the past, when the Agency looked to technical people for a miraculous technical fix to problems, the technical people tended to do what they know best, which was to install new hardware and software, often at a disconcerting rate. With the new shift to seeking balanced technical and nonsolutions, users have an opportunity to temper the rate of technical change. However, if users and managers do not choose to be involved in the process, the technical people will continue to fill the vacuum.

SUMMARY

The Forest Service is under increasing pressure to manage its information more effectively. The Agency has recently adopted an Information Management Framework to guide it in doing so. If the effort is to be successful, every employee needs to be part of the team.

Marketing Watershed Management in the U.S. Forest Service: An Example From the Willamette National Forest, Pacific Northwest Region

Deigh T. Bates[1] and Annie Vrijmoet[2]

Abstract.--This paper discusses the development of a strategy to market Forest Service watershed management programs for various audiences. The procedure used on the Willamette National Forest is examined, and recommendations are made for use of this concept elsewhere. Ideas for a regional or national approach are also presented.

INTRODUCTION

At one time watershed protection played a more dominant role in the management philosophy of the National Forests. Watershed specialists and foresters in the early part of this century discussed, experimented and studied at length the role of forest cover in ameliorating floods in large river basins especially along the Ohio and Mississippi River valleys.

Additionally, in 1910 the Forest Service in conjunction with the Weather Bureau initiated the world's first paired basin study at Wagonwheel Gap, Colorado. The early days of the Forest Service could thus be characterized as being heavily committed to watershed protection, but by the 1950's this commitment had subsided in favor of 'timber fundamentalism' (Coates, 1986).

Today the Forest Service watershed management specialist is almost an 'unseen resource' in a large bureaucratic organization that over the past few decades has seen continuing emphasis on timber management and production. Due to the technical nature of their activities, the watershed specialist communicates on a technical level and does not easily speak with others not familiar with technical language or principles. Even to resource managers, the concepts of hydrology, soil science and watershed management are foreign and best left to the 'experts', i.e., watershed specialists.

Over the years watershed specialists have relied heavily upon technical analysis and years of field experience to assure their managers that watersheds were and are functioning as expected. While this has resulted in good land stewardship, it has also resulted in little political or cultural support for watershed management activities, as well as a lack of recognition among the general public.

With the recent upsurge of interest in the cumulative effects of forest management activities on water quality and quantity, and the overall heightened environmental interest by the general public, the role of the Forest Service watershed specialist is rapidly changing. The public is becoming more interested and involved in how the nation's watershed's are managed. As they begin to recognize the values contained in public watersheds, such as recreation, wildlife and fisheries habitat and a supply of potable water this involvement will surely grow.

Not since the early years of the Forest Service has there existed such an opportunity to educate and incorporate the public in management of National Forest watersheds and as a result elicit support for watershed activities both politically and financially.

Recognizing this opportunity the Pacific Northwest region began exploring ways of marketing watershed management to the general public. Initial efforts have resulted in the poster/brochure, WATERSHED MANAGEMENT: Beyond the Dry Facts. This paper will describe the development of that poster/brochure, give recommendations for similar projects and present some ideas for future efforts which could be done at the local, regional or national level.

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CONCEPT DEVELOPMENT

Operating from the premise that little or no name recognition existed among the general public for Forest Service watershed specialists, discussions began in early May 1991 during a Region Six watershed conference. Taking the initiative but having only a vague idea of how to proceed with making such a marketing project a reality, the Willamette NF chose to work with a professional design firm, local and small enough to be very accessible during all stages of concept development, design and production, resulting in what we believe to be the best possible product. The Willamette selected, Vrijmoet Design, to develop our objectives and challenges into a concept direction and recommend and produce a marketing piece. Use of an outside firm allows for a perspective, especially when dealing with the general public, that is not always present within the agency.

Informal research to support our impression that watershed management suffered from a lack of name recognition was conducted in the form of informal interviews of local subjects. Interviews were in no way intended to be scientific or statistically sound but rather meant to validate or negate our initial perspective in a qualitative sense. If we had found more name recognition among those interviewed we would have oriented the message of the poster/brochure to a different level.

The design firm assisted in defining the challenges as follows:

1) misunderstanding of the definition of watershed"
2) lack of awareness of the existence of watershed management specialists, therefore little or no name recognition.
3) lack of appreciation for specific efforts on the part of watershed management specialists.
4) lack of general public support that would translate to political or financial support.

Therefore our objectives were designed: "To promote the image of Watershed Management as protectors of the water supply for purposes of recreation, drinking water and wildlife and fisheries management. To educate as to the role Watershed Management plays in keeping water safe and clean for the consumer."

Based on the informal research and in light of our desire to improve awareness, appreciation and support of watershed management's activities and value, both politically and socially, the recommendation was made by the designer to produce a marketing piece that would both educate and promote on a very basic level.

Design of the poster/brochure went through a number of phases. Initial brainstorming ideas ranged from development of a standard agency brochure to a large simple poster with a single caption. These concepts were presented to the watershed management group in the R-6, Regional Office. This was done for a number of reasons. First, to gain support for the project,(especially financially); and second, to assist with project definition. Ideas that lead to final design were presented and promoted at this meeting.

Following that first meeting it was decided to employ photos interspersed with simple, non-technical text. The photography was selected from scores of images supplied by the designer from stock photo supply houses. We felt it was imperative to use only high quality photography, both to get the best quality print reproduction and as a reflection of the quality of our work in watershed management.

The content of the text was provided by the Forest Service and given to a professional writer for copy writing. The intent was to take out all of the technical language and jargon so that the brochure became as readable, understandable and 'people friendly' as possible. We defined our audience as including individuals who might not know what a watershed is, who would know almost nothing about the path that water takes to reach their faucets, and who certainly were unaware that watershed specialists had anything to do with clean water for recreation and wildlife. Our experience was that even with the best of intentions Forest Service authors tend include too much agency 'lingo' in their writing for general consumption. We also feel that by making the text 'people friendly' it becomes an invitation to the public to begin discussions about watershed management on a level appropriate to their interest. Final approval of the copy was given by the Forest Service.

The recommended format was specifically designed to reach our audience; to stand out in a crowd of brochures all competing for attention; to give them a reason to open it up and a reason to hang onto it, even hang it on the wall.

DISTRIBUTION

Perhaps the most important aspect of the project is distribution. Time and energy should be spent on being sure that the product gets to the audience you want to reach. At this stage the Forest and the design firm met with the R-6, Regional Office to discuss a strategy for distribution. It was decided to distribute the poster/brochure at both the agency level as well as to the public. We used the forest plan mailing list from the Willamette NF to determine an appropriate public distribution. To accompany this distribution we wrote a letter oriented to each type of mailing. Additionally, we included a small card in the copies going to the general public stating that Forest Service representatives would be happy to come and speak about watershed management and local watershed issues and directing them to contact their local district office or supervisor's office.

Distribution to the forests in the Pacific Northwest Region was kept to a minimum as was initial distribution to the public. For instance, only 25 copies were sent to each forest and to other regional offices around the country and the Washington office. We did not want to overwhelm offices with copies and felt that additional copies could be supplied upon request as demand warranted.

Distribution to the general public can happen in a number of ways. Events such as Free Fishing Day in Oregon and Washington are prime opportunities for distribution. Forest Service booths at state and county fairs are another avenue for distribution.

Recommendations

1. Employ the services of a professional design and advertising agency.
2. Target text to a specific audience. Use the services of a professional writer to eliminate agency 'lingo'.
3. Use a non-traditional design - colorful and attractive.
4. If photography is planned use either a photographic stock house or have pictures taken by a professional. Do not use in house Forest Service photography.
5. Do an on-site press check.

WHERE DO WE GO FROM HERE?

There are numerous opportunities to promote watershed management activities in the Forest Service. Such opportunities are, in our opinion only limited by the imagination and willingness of those working in the field. While funding is a constant concern, especially in these days of limited budgets, there still exists many avenues for such promotions. The success of any such project is predicated upon the willingness of Forest Service watershed management specialists to take personal accountability and become involved in promoting their skills both internally and externally.

A single poster/brochure will not accomplish all of the goals of marketing the role and abilities of watershed specialists on either a national, regional or local level. In the Pacific Northwest Region we believe it would be appropriate to build upon the existing poster/brochure by orienting the photography and text to eastside Oregon and Washington forest watersheds. This could be done simply and inexpensively and would tend to localize the poster/brochure for distribution in those areas.

We feel that once a certain level of name recognition is gained through the use of such techniques as the poster/brochure and the personal involvement and promotion by watershed specialists that more subject oriented material can be developed of a more technical nature. This may include material on water monitoring activities, long term site productivity or riparian management. In all cases we feel it is necessary to clearly define the intended audience prior to development of the material and be sure to orient the product to whom it is intended.

On a more national scale, certain magazines offer public service advertising space free of charge. The Smokey Bear advertisements are an example of such public service advertisements. The cost for these ads would be in development and design, a minor expense in reaching a broad audience.

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Rocky Mountains

Southwest

Great Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota

*Station Headquarters: 240 W. Prospect Rd., Fort Collins, CO 80526